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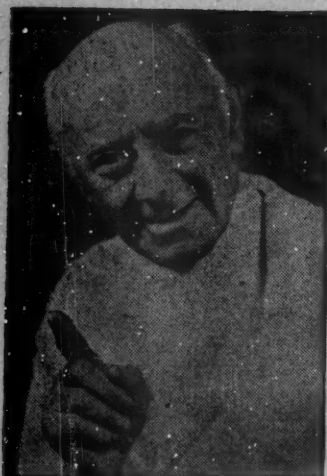
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VASCULAR INJURIES OF THE EXTREMITIES IN BATTLE CASUALTIES

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THE TREATMENT OF PATIENTS with arterial injury has presented a particularly difficult problem for the military surgeon. It became evident early in this war that ligation of the large arteries of the lower extremity resulted in a disappointingly high incidence of gangrene, and that the outlook in such cases was not as hopeful as had been anticipated. Predictions of extremity survival after arterial ligation based on experience with vascular surgery in civilian life cannot be applied to patients with vascular wounds in warfare. In civilian practice one is more frequently dealing with the treatment of vascular lesions of some duration, in which collateral circulation has been established to some extent, making ligation less hazardous. Elective arterial ligations cannot be compared with immediate ligations for severed arteries in extremities in which extensive soft-tissue and bone damage, with destruction of collateral vessels, is present. Furthermore, the beneficial effect on collateral circulation of measures directed toward promoting vasodilatation cannot be expected to pertain so effectively in these severe injuries. On the other hand, the difficulties in vascular surgery among battle casualties has been a stimulus for the application of all established methods of treatment and for the introduction of new procedures. The use of sulfonamides and penicillin in battle casualties today, resulting as it has in a low incidence of wound infection, has made possible attempts to save extremities deprived of their blood supply, which, in World War I, would have been considered for early amputation as a prophylaxis against gas gangrene. The surgeon working in the forward areas today, therefore, has had a larger proportion of patients with damaged arteries in which restoration or improvement of the existing circulation has been the paramount problem.

In this communication we shall report our experiences in the management of 100 consecutive patients with arterial injuries of the extremities encountered in an Evacuation Hospital during an 11-month period in the campaign in Northern Europe. Only the major arteries will be considered: In the upper

extremity, the axillary and brachial arteries; in the lower extremity, the femoral and popliteal arteries. Earlier experience in the North African and Sicilian campaigns had shown us that a special study of these cases was indicated and special forms for recording pertinent data were instituted in the hospital. The results which we shall present are the immediate results given in terms of gross survival or death of some part of an extremity. All patients who left the hospital with viable extremities were classified as good results. Wherever there was evidence of impaired circulation or gangrene, the case was classified as a poor result, without qualification. We cannot report the late results in terms of the extent of limb loss, since follow-up studies are not available at this time. The period of hospitalization for these patients varied from one to 14 days and did not, as a rule, extend beyond the time required to determine the status of the extremity after surgery. As soon as adequate circulation was assured the patient was sent to the rear. If gangrene ensued, amputation was performed at once in the moist and gas-infected cases, but a line of demarcation was awaited in nontoxic patients, some of whom were sent to the rear unamputated after a period of seven to ten days of observation.

DIAGNOSIS

The diagnosis of arterial injury in extremities in most cases was not difficult. Certainly, the diagnosis was easy for the surgeon in those patients with free arterial bleeding who were admitted to the hospital with a tourniquet in place. However, we have found in our hospital that one must be especially on the look-out for these injuries so that no time be lost in the preparation of these patients for surgery. Whenever the diagnosis was missed, it was usually the result of inadequate examination during periods when large numbers of casualties arrived at the same time. In echelons forward of the hospital greater emphasis could be placed profitably on diagnosis of vascular injuries and patients with these wounds should be sorted out there for direct evacuation to the hospital. Palpation of pulsations in the extremity with comparison between those in both limbs should be enough to make a tentative diagnosis; certainly, all suspicious cases could be gathered together in this manner.

The presence, unilaterally, of a cold, pulseless extremity distal to a wound is an obvious indication of arterial injury. However, in two types of cases the diagnosis is less obvious. Badly shocked patients with no palpable peripheral pulsations in any extremity must be reexamined frequently for evidence of arterial injury as their condition improves. In addition, it is possible to have palpable distal pulsations in cases of small lacerations of arteries. The most easily overlooked cases are those in which the color and warmth of the extremity seem normal at the first cursory examination. A routine search for pulsations in both extremities prevents mistakes in diagnosis in the patient with a pulseless extremity of normal appearance. The Tycos sphygmomanometer, used as an oscillometer, is helpful in detecting feeble pulsations. An additional sign of value in suspected vascular injuries is the presence of a firm swelling in the region of a small wound and particularly in the region of the popliteal space and of Scarpa's triangle. Hematomas which are the

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result of injury to a vein rarely cause arterial compression even in such a closed space as the popliteal fossa. In each case suspected of arterial injury a rough neurologic examination for sensation and motor function should be made if practicable. Injury of nerves is frequently associated with arterial damage since these two structures are in close anatomic association. In some cases arterial wounds may exist without being suspected by examination before operation. In those instances in which metallic foreign bodies appear to be lodged near major vessels in the roentgenograms, a careful exploration at débridement will sometimes detect small arterial lacerations. Routine palpation for thrills and auscultation for bruits indicative of arteriovenous fistulae should be a part of every examination in wounds suspected of major vessel injury. It is rare, however, to find the classical signs of arterial aneurysm or arteriovenous fistula early after injury. In only one case in this group were the classical signs present.

PREOPERATIVE TREATMENT

It is especially important in vascular injuries to prepare the patient for operation as expeditiously as possible since time is such an important factor in saving extremities. The circulating volume of blood should be restored as completely as possible so that the extremity need not labor under the additional handicap of blood with a decreased oxygen-carrying capacity.

Plasma was used in the preoperative treatment in 52 of the 100 cases, and had been given for the most part at the Battalion Aid or Clearing Station prior to admission as a means of temporarily combating shock so that the patient could be transported to the hospital. In the preoperative and shock wards it was used in the treatment of patients in mild shock and those in whom there had been little loss of blood.

Blood transfusions were begun immediately in the hospital. Many of these patients had lost upwards of two liters of blood and shock was frequently severe. Patients with vascular injuries were found to require much more blood than the majority of other wounded. The best guides for shock therapy were the blood pressure values and the hematocrit readings. Not infrequently, because of severe shock, operation could not be performed at the optimum time and saving the extremity was secondary to saving life. This was especially true in patients with multiple wounds. Blood transfusions of 500 cc. to 3,000 cc. were given to 55 of the 100 patients.

The urgent problem of active arterial hemorrhage in the preoperative period did not arise too frequently since the soft-tissues usually controlled external bleeding and hematoma formation resulted. When it did occur, it was usually the result of a rise in the patient's blood pressure while he was being treated for shock with blood transfusions. If the bleeding vessel could not be visualized and controlled quickly, a blood pressure cuff tourniquet was applied. Tourniquets were ordinarily released every 10 to 15 minutes. In order to avoid the prolonged use of tourniquets, transfusions of blood were given under pressure and the patient brought to surgery as soon as possible. At times it was necessary to move the patient to the operating room while

he was in shock, and, under anesthesia, control the bleeding vessel, after which the major operation could be delayed until the optimum time. The use of tourniquets is sometimes unavoidable, especially during the period before the patient reaches the hospital. They are used, however, more frequently than necessary, and have been known to do a great deal of harm. Direct pressure dressings in the wound or the application of hemostats to vessels are much more efficient and desirable methods for controlling bleeding in the usual case.

Oxygen was used routinely during the preoperative period in patients in shock in order to maintain the oxygen content of the arterial blood reaching the devitalized limb by collateral circulation at as high a value as possible.

Sulfadiazine was administered by mouth in doses of one gram every four hours. All casualties had received their initial dose of four grams before reaching the hospital. Penicillin therapy was begun preoperatively, with an initial dose of 40,000 units given intramuscularly and it was continued in doses of 20,000 units every two hours. American soldiers were given one cubic centimeter of tetanus toxoid and prisoners-of-war 1,500 units of anti-tetanus serum, as a prophylaxis against tetanus.

OPERATIVE TREATMENT

Almost all operative procedures were undertaken under nitrous oxide-oxygen-ether anesthesia. At times anesthesia was induced with pentothal-sodium and maintained with inhalation anesthesia. If the operation was one of short duration, pentothal-sodium alone was used.

Approach to the damaged artery was made through the extended existing wound wherever possible. Since débridement of the wound tract was of primary importance, an exposure adequate enough to reveal all parts of the wound tract was made. In an extremity that could be expected to have a deficient circulation, nothing was of greater importance than the removal of all foreign material and devitalized tissue which could act as a nidus for the development of infection. In the dissection of these wounds particular care was used to avoid damage to all vascular radicles which could provide collateral routes for circulation to the extremity. If an elective wound was necessary to provide an efficient approach to the injured vessel, the débridement of the wound or wounds was completed first and clean instruments were used for the elective approach. If active bleeding was present before operation or expected in the approach to the vessel, a proximal tourniquet was used. In wounds of the proximal portion of the superficial femoral artery, it was sometimes necessary first to expose and control the common femoral artery. Rarely, the external and common iliac arteries were exposed and arterial tourniquets placed in order to avoid troublesome bleeding.

The average time between wounding and surgery was 15.5 hours. The shortest time in this group of patients was four hours and the longest 51 hours. In the following paragraphs we shall outline the various operative procedures employed and the indications used for each.

In Table I the results of the various procedures employed for each of the

several arteries are tabulated in terms of good or poor results for extremity survival.

Primary Amputations: In nine, or 9 per cent, of the total of 100 patients treated, primary amputation was necessary. All of these patients had wounds which were at least 16 hours old and which were extensive and complicated by the presence of a compound fracture. This group was not in the traumatic amputation classification. The major arteries were severed and thrombosed and no retrograde bleeding was present in the distal portion of the severed vessel. The portion of the extremity distal to the wound was cold and cyanotic, and in several cases early rigor had appeared. The decision to amputate was never made without consultation and if there was any question of the advisability of amputation, it was delayed for 24 hours. If amputation was necessary, it was undertaken at the lowest level possible.

Arteriorrhaphy: Repair of a lacerated artery was undertaken in five cases, or 5 per cent of the total. The femoral artery was repaired three times, the axillary once, and the brachial artery once. In the five patients in whom arteriorrhaphy was attempted the tissue damage was slight in three, and moderate in two. There were no associated long bone fractures and no arterial thrombosis existed.

In two of the three patients with injury of the femoral artery, the extremity had a normal appearance before operation and the dorsalis pedis and posterior tibial pulsations were present. The arterial wounds were discovered unexpectedly in the course of the débridement. The wounds extended through the intima and were one centimeter in length. With proximal and distal control of the vessels by means of soft rubber local tourniquets, suture was performed by coapting intima-to-intima with interrupted fine silk stitches, and reinforcing the latter with a row of sutures through the muscular coat. In both of these cases a good circulation was retained and the patients were transferred with distal pulsations present in warm extremities. In the third case involving the femoral artery the distal part of the extremity was cold and white, before operation, and no pulsations were palpable. The arterial wound involved the muscular layer only but the vessel was contused. The defect in the muscularis was repaired by interrupted fine silk sutures. Color, warmth and peripheral pulsations returned to the extremity after operation, and the patient was evacuated with a normal circulation in the extremity.

The wound of the axillary artery which was repaired was discovered at operation in a patient whose arm had a normal appearance and a normal radial pulsation before operation. The arterial wound was 0.5 centimeter in length and involved the muscular coat only. Repair was made with interrupted silk sutures and no impairment of circulation resulted.

The largest arterial wound repaired was a laceration of the brachial artery three centimeters in length. The patient's hand was cool and cyanotic, before operation, and no radial pulsation was present. After surgery the color and temperature returned to normal but a radial pulse was not at any time palpable and thrombosis may have occurred at the site of the repair.

Repair of a lacerated wound of an artery should be attempted in those

cases in which wounds of the extremity have only moderate tissue damage and in which the arterial wound is small and there is no marked circulatory deficiency. In these, approximation of the wound edges can be effected easily and quickly without prolonged interruption of the blood flow and without appreciable decrease in the size of the lumen by the repair. Repair of an extensive arterial wound often results in obliteration of the lumen and an arterial anastomosis is the better operation in such cases if an attempt at maintaining the arterial continuity is to be made.

Ligation: Ligation of the injured artery was done in 70, or 70 per cent, of the total of 100 cases. While some of these 70 cases might have had an

TABLE I
RESULTS OF TREATMENT IN 100 PATIENTS WITH VASCULAR INJURIES

Treatment	Axillary Artery		Brachial Artery		Femoral Artery		Popliteal Artery		All Arteries	
	Good Result	Poor Result	Good Result	Poor Result	Good Result	Poor Result	Good Result	Poor Result	Good Result	Poor Result
Primary amputation	0	1	0	4	0	1	0	3	0	9
Arteriorrhaphy.....	1	0	1	0	3	0	0	0	5	0
Ligation.....	3	2	24	11	3	14	3	10	33	37
Nonsuture anastomosis.....	0	1	1	0	1	4	0	1	2	6
Débridement only..	0	0	1	1	1	1	4	0	6	2
Totals.....	4	4	27	16	8	20	7	14	46	54

attempted anastomosis, we were handicapped by the lack of material early in the campaign. In addition, it must be said that in busy periods with large numbers of casualties of serious nature there was insufficient time for performing long operations, the successful outcome of which was doubtful and the hazard considerable in the severely wounded. If the vessel was severed, the devitalized ends were excised and the proximal and distal ends were ligated doubly with chromic catgut sutures. If the vessel was not severed, the division was completed. Quadruple ligation was practiced as a rule, and the companion vein was similarly ligated and severed. In those arteries in which a small laceration had resulted in thrombosis of long-standing, the thrombosed section was excised and the ends were ligated.

Early in the campaign the wounds were frosted with a mixture of sulfanilamide and penicillin, but later this practice was discontinued. Elective wounds were closed in layers if the other wounds provided adequate drainage for the tract but the primary wounds were partially and loosely closed only when they had been well-extended. Loose vaselined strips were placed in the wound and covered with dry gauze dressings. The extremity was usually encased in a split-plaster encasement, whether or not a fracture was present.

Of the 70 patients in whom arterial ligations were performed, 37 had gangrene of some portion of the extremity after operation, and 33 had a viable extremity. The results after ligation varied in the case of individual arteries and are listed in Table I. In subsequent paragraphs we shall discuss the significance of arterial ligations at different anatomic levels.

Arterial Anastomosis: The anastomosis of severed arteries in war wounds with extensive damage to the collateral vessels would seem to be the only

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method of saving some of these extremities. Suture anastomosis offers many difficulties under the best of conditions and in patients in whom extensive wounds have resulted in considerable damage to arteries the technical difficulties are increased by shortening and retraction of the vessels making approximation of the cut ends impossible without great tension. After attempting suture anastomosis of the popliteal artery, we abandoned the method as not practical in the usual type of case we encountered, and have concentrated our efforts on the nonsuture method of blood vessel anastomosis described

TABLE II
BLAKEMORE NONSUTURE ARTERIAL ANASTOMOSIS

Case No.	Artery	Time Wounded before Surgery in Hours	Tissue Damage	Heparinized	Result in Extremity
1.	Axillary (third part)	12	Moderate	No	Gangrene
2.	Brachial, proximal to bifurcation	4	Moderate	No	Viable arm
3.	Common femoral at bifurcation	9	Moderate	Yes	Gangrene
4.	Superficial femoral]	4	Slight	Yes	Gangrene
5.	Superficial femoral	9	Slight	No	Viable leg
6.	Superficial femoral	10	Moderate	No	Gangrene
7.	Superficial femoral	14	Severe	No	Gangrene
8.	Popliteal between the geniculates	10	Moderate	No	Died at operation

by Blakemore, Lord and Stefko.¹ During the Sicilian campaign two of these anastomoses were attempted upon patients with severed popliteal arteries not reported in this series. Both anastomoses were unsuccessful but we felt that the method was the best available and offered promise especially if cases were carefully selected and more experience gained in the technic.

Briefly stated, nonsuture blood vessel anastomosis is accomplished by bridging the gap between the severed ends of the artery by using vitallium tubes which are lined with a section of vein, usually the great saphenous. The vitallium tubes are fitted into the arterial segments to be joined and tight junction is accomplished by ligature. Suturing is avoided and a continuous intimal lining for blood flow through the bridge is provided. Excellent descriptions of the method are given in the publications of Blakemore, *et al.*^{1, 2, 3}

We performed vitallium tube anastomosis in eight of the 100 patients in this group. The data on these patients is presented in Table II. The small number of cases in which an anastomosis was undertaken cannot be interpreted as an index of the possible application of arterial anastomosis to war wounds. We were limited in employing the method in a larger series for a number of reasons: First, we selected those in which we felt a reasonable chance for trial of the method could be obtained. Only one patient in whom there was severe tissue damage of an extremity was subjected to anastomosis and in none was there a compound fracture present. Patients who could be brought to operation as soon as possible after being wounded were taken. In Table II the time between wounding and operation is seen to be between four and 14 hours, with an average of approximately nine hours. There were two patients operated upon within four hours—the most desirable time. Unfortunately, the time factor is an uncontrollable one. On the other hand, with the exception of one case (Patient No. 2), we performed no anastomoses on

brachial arteries since we felt that anastomosis of this vessel would not be a good test of the efficiency of the method. Results after brachial artery ligation are relatively good, collateral circulation in the arm is infinitely better than in the leg, and in the absence of oscillimetric studies and arteriography we believed there might be confusion in crediting the results obtained. Finally, we were limited in our supply of vitallium tubes and heparin until the latter part of the campaign.

We found in most cases, and even in the presence of free retrograde bleeding from the severed distal end of the artery, that suction would remove a fair-sized thrombus. In two instances ureteral catheters were passed down the distal end of the artery and the vessel irrigated. Heparin was available for use in only two cases, and in these was administered by intravenous drip. In addition to heparinization of the patient, heparin was instilled directly into the artery after completion of the operation.

Vitallium tube anastomoses were performed in five patients with femoral artery injury. In four of these the superficial femoral artery was injured and in one, an anastomosis was effected after ligation of the deep femoral branch for a wound at the bifurcation of the common femoral artery. The posterior tibial and dorsalis pedis pulsations were not present in any of these patients before operation. A satisfactory anastomosis was accomplished in each case and the distal arterial segment pulsated while the anastomosis was under direct observation but at no time were the posterior tibial and the dorsalis pedis pulsations detected postoperatively. In only one of the five cases was a viable extremity obtained (Patient No. 5). This patient had been wounded nine hours previously, and, on admission, his extremity was cool but not excessively cold, and pulsations were absent. After operation the leg became warm and pink, and remained so until evacuation. In a follow-up note from the patient five months after injury he stated that his leg was entirely normal and that he was walking on it without trouble. The condition of this patient's leg before operation was such that we believe that collateral circulation may have placed a larger rôle than the anastomosis in saving the leg.

Patient No. 4 seemed to us an ideal one for trial of the method. This patient had a small clean knife wound of the superficial femoral artery in Hunter's canal. He was fully heparinized beginning at operation. After operation, the distal arterial segment presented a good pulsation. The final result, however, was gangrene of the lower leg requiring amputation at its midportion, 14 days after injury.

One anastomosis on each of a popliteal, an axillary and a brachial artery was performed. The patient in whom the popliteal artery was anastomosed (Patient No. 8) died on the operating table after operation had been completed upon being turned over on his back. Postmortem examination revealed a pulmonary artery embolus. In the case of the patient with a severed axillary artery (third portion), we had little hope of success since the forearm and hand were both extremely cold and slight mottling of the skin was already present. Amputation at midforearm was necessary ten days after operation. The one patient upon whom anastomosis of the brachial artery was done died

on the fourth day with anuria as a result of "crush" syndrome. He had been pinned under a vehicle for two and one-half hours. However, the hand and forearm were viable on the day of his death. Before operation no radial pulsation was present. Twenty-four hours postoperatively the radial pulse was palpable. In this case, however, the brachial artery had been severed just proximal to its bifurcation, a site at which ligation is usually quite safe. In fact, we have not infrequently noted that radial artery pulsations may become palpable 24 to 72 hours after ligation of the brachial artery. Postmortem examination showed that there was no thrombus in the anastomosis. Excluding the patient who died at operation, there were seven cases in which the extremities were observed postoperatively. In five, gangrene resulted and amputation was necessary. In two, a viable extremity was obtained. In both of these latter cases, however, we believe that collateral circulation was better than in the other cases in which anastomosis was performed. The failures, on the other hand, cannot be attributed to the method since a successful anastomosis will certainly deliver blood to the distal arterial segment. We are of the opinion that thrombosis and spasm in the distal arterial tree are the greatest detriments to success. Nevertheless, we believe that the method of Blakemore has certain disadvantages, especially in field surgery. The operation requires over two and frequently three hours to perform including the making of the vein graft bridge. We usually selected the great saphenous vein from the uninjured leg although femoral veins were used on two occasions. A careful débridement must be done and this is time-consuming. Early experience showed us that a smaller vitallium tube must be used than one would judge necessary or splitting of the intima of the artery will result on attempting to force a tube of desirable size into the arterial stump. The resulting diminution in the lumen at the anastomotic site is, in itself, not considered to be important since diminution in diameter has been shown experimentally to be compensated for by an increased rate of blood flow.⁴ The segment of vein between the two vitallium tubes, however, is thin-walled and expands considerably, resulting in what might be compared to a fusiform aneurysm. It is our impression that arterial pressure is reduced in passing through the vein graft. This impression is corroborated by the appearance of the stream of blood which emerges from the distal end of the bridge, and by the fact that the pulsation in the distal segment of the artery is weaker than in the proximal segment after completion of the anastomosis. A rigid tube of metal or plastic material might overcome this objectionable feature, although we have not used such tubes.

Conservative Treatment: A total of eight patients with vascular injuries were treated conservatively, i.e., only débridement of the wound, or wounds, was performed (see Table I).

In three cases arterial spasm was present. Two patients had spasm of the brachial artery exposed at operation. In one, there was a segment of the artery four centimeters long, proximal to the profunda branch of the brachial artery in spasm; in addition, a compound comminuted fracture of the humerus, radius and ulna were present. Perivascular infiltration with

procaine solution followed by perivascular sympathectomy failed to relieve the spasm. Postoperatively, cervical sympathetic block was performed, producing Horner's syndrome. The spasm was apparently not relieved and gas gangrene developed, requiring amputation on the third day. In the second patient, the brachial artery was in spasm below the profunda branch. The extremity was warm at all times but there was no palpable radial pulse. After operation the radial pulse became palpable following a cervical sympathetic block, and the patient was evacuated with a normal circulation in the extremity. The third instance of spasm was encountered in a patient with a shell fragment wound of the thigh in which the missile appeared, roentgenologically, to be lodged near the femoral artery. The foot was cold and white, pulsations were absent, and there was a fair-sized hematoma in the thigh. Paravertebral lumbar sympathetic ganglia block with procaine was done within four hours of injury after which the dorsalis pedis and posterior tibial pulsations became palpable. The patient was evacuated on the third day, with good circulation in the leg. It is possible that a small arterial laceration was present and that a false aneurysm or arteriovenous fistula may have later formed in the hematoma.

The fourth patient in this group, in which débridement alone was done, presented with an arteriovenous fistula of the femoral vessels in Hunter's canal. His leg and foot were warm and had good color but the peripheral pulsations were absent. Since early operation for arteriovenous fistula is not in keeping with good practice, and the patient had a viable extremity, the fistula was not explored. There were multiple leg wounds present. On the fourth postoperative day crepitation was felt in the tissues of the leg and the patient developed toxemia. The foot became cold, and it was obvious that gas-forming organisms had jeopardized the circulation. Supracondylar amputation of the femur and excision of the fistula was done, and recovery followed.

Four patients with perforating gunshot wounds of the popliteal space were treated conservatively. All showed essentially the same clinical picture throughout their stay in the hospital. On admission to the hospital, they were found to have tense hematomas and wounds of entrance and exit one centimeter to one and a half centimeters in size, located so as to indicate that the wound tract passed through the deepest part of the popliteal space. In no case was there a fracture of the femur or tibia, and all patients were in good condition. The extremities distal to the wound were warm and had good color in three patients and was cool and pale in the fourth. No dorsalis pedis or posterior tibial pulsations could be elicited in any of the patients. The skin wounds were débrided under local anesthesia. The patient with the cool foot had one lumbar sympathetic block which resulted in a warmer but still pulseless extremity that did not again become cool. No other treatment was instituted except the routine penicillin and sulfonamide therapy. The injured extremities of these four patients remained warm but pulseless during their hospital stay of seven days. Although the final examination of each patient revealed no sign of aneurysm or arteriovenous fistula, it is true that signs of

these lesions require time to develop and for this reason are infrequently diagnosed in the early period following wounding.

While it must be admitted that in these four patients with wounds of the popliteal space there is not *prima facie* evidence of an arterial wound since the vessels were not exposed, it seems reasonable to suppose that the vessel had been lacerated or severed. If the condition were spasm only in segments of these arteries, it probably would have disappeared and distal pulsations would have reappeared in 24 hours, especially in the case which had the sympathetic block. We believe that adequate circulation already existed and, therefore, surgical interference could add little to the chance of survival of the extremity.

We were led to practice this conservative method of treatment because of our experience with three similar cases in which the ligation of severed popliteal arteries resulted in an avascular extremity, in spite of preoperative evidence of adequate circulation. The reason for this occurrence of gangrene after ligation in a presumably viable leg is not clear. One might speculate that some blood reached the leg through the hematoma. The question of the ultimate fate of these extremities cannot be answered since follow-up studies are not yet complete. However, we felt justified in allowing the collateral circulation to develop even though an aneurysm or an arteriovenous fistula might develop at a later date. The only urgent indication for surgical exploration in wounds of this type is that of free bleeding. The principal danger of not performing the usual débridement is infection, and especially by gas-forming organisms. It is rather uncommon, however, for gas gangrene to develop from a perforating bullet wound in an extremity with an adequate circulation under drug therapy. These patients must be carefully observed at frequent intervals during the immediate postoperative period. Late operation for aneurysm or arteriovenous fistula must be contemplated.

POSTOPERATIVE TREATMENT

Routinely, penicillin and sulfonamide therapy, initiated preoperatively, was continued. Transfusions of blood were administered as indicated by hematocrit studies. The injured extremity usually was placed below the level of the heart to promote venous stasis and maintain arterial circulation at its maximum efficiency.

Alcohol, administered by mouth or intravenously, and papaverine subcutaneously were used in many cases, and a lowered temperature was maintained in the extremity in a few patients by use of the small amount of ice available. All of these measures, however, were not appreciably effective.

Block of the lumbar sympathetic ganglia with 2 per cent procaine injection was done 139 times in the 100 patients. In 25 of the 49 lower extremity cases a total of 132 blocks was performed. Cervical sympathetic block was done in five of 51 patients with upper extremity wounds. Two lumbar sympathetic ganglionectomies were done in patients with injury of the popliteal artery. The first block was usually done on the operating table at the close of the operation. This was followed-up with blocks done on the ward at

intervals of six to 12 hours. They were continued until the prognosis of the extremity was established. The question of the efficiency of each procedure cannot well be answered. In an extremity in which the distal circulation was already much impaired, a complete interruption of the sympathetic nerve pathways might show little evidence of its effect. Subjective changes were sometimes mentioned by the patient when no objective signs were evident. Because of this lack of positive evidence, the establishment of an actual block in every case cannot be affirmed. In those cases in which circulation was not markedly impaired, and in which progress to avascularity had not gone too far, the proof of an actual block was less questionable. The type of case in which sympathetic block was most likely to be effective rapidly and to be of unquestioned value was that of an extremity in which the artery was in spasm. One block was sufficient to change a cold, white, pulseless extremity to a more normal state of circulation. Sometimes needles were left in place after the injection of the procaine and, when the success of the block was apparent, 5 cc. of 95 per cent alcohol were injected into each needle.

In the last phase of the campaign we planned to do lumbar sympathetic ganglionectomies on selected cases in whom no contraindication to an additional operation existed. Only two were done, both in patients with wounds of the popliteal artery. One developed gas gangrene in the extremity shortly after surgery and the other patient was transferred because of rapid movement of the hospital on the fifth day, with an avascular foot. Our experience with this procedure as an adjunct has been limited to these two cases, making it impossible for us to judge its value.

We are unable to evaluate accurately the effect of the 139 sympathetic ganglion blocks on the extremity survival rate in this series of cases. One can hardly expect much of the procedure in the type of extensive injury of the extremity in which there is great damage to the collateral vessels as well as to the principal artery. There are simply an inadequate number of vessels remaining. In no case did this procedure appear to reverse the progress from an avascular state in patients with severed arteries. In almost all cases, the status of the circulation in the injured extremity was apparent at the end of the first 24 hours. In only two cases was it felt that blocking was an important factor in tipping the balance in favor of a good result.

GAS GANGRENE

Gas gangrene of the wound and of the extremity distal to the wound was diagnosed clinically in 12 of the 100 cases. Three were upper extremity wounds, with brachial artery injuries, and in nine the lower extremity was involved with injury of the femoral artery in five patients, and of the popliteal artery in four. The average age of the wounds at the time of operation in this group was 21.5 hours, the extremes being nine hours for the shortest period, and 48 hours for the longest. The degree of tissue damage was severe in ten wounds and moderate in two; and in 11 of the 12 cases compound fractures existed in the injured extremity. The diagnosis of gas gangrene infection was made, or suspected, in three patients at the time of the primary operation,

and amputation was performed in one case. In the remaining nine patients the infection was discovered at intervals of 12 hours to four days following operation. In four of these patients wide incision and excision of necrotic tissue was performed in an effort to save the extremity. One of these four patients died after operation, and the remaining three came to amputation at a later date. Of the total of 12 patients with gas gangrene developing in avascular extremities, 11 were subjected to amputation, and three patients died of the infection.

The recognition of gas-forming organisms as a complication was one of the most important parts of the postoperative care. The split-plaster encasement was spread widely in order to allow complete inspection of the extremity and frequent palpation for the presence of crepitus, which was one of the earliest signs of gas infection onset. In the more virulent forms of infection a severe constitutional reaction might presage its presence, but this reaction seemed to be the exception rather than the rule. Gas gangrene in the avascular extremity seldom presents the severe symptoms and signs of primary infection. The routine administration of sulfadiazine and penicillin may, in addition, have lessened the severity of the constitutional signs.

DEATHS

Of the 100 patients in this series, six died in the hospital. We have no knowledge at this time of subsequent deaths among the group after evacuation to hospitals in the rear. Gas gangrene was the cause of death in three cases. One of these patients died a few hours after primary amputation of a lower extremity for an extensive infection. Another patient died four hours after wide incision and excision of necrotic tissue in a leg with a widespread infective process. The third patient succumbed on the tenth day following a re-amputation in an effort to halt an anaerobic infection. A severe hemolytic blood transfusion reaction, with anuria, was the cause of death in the fourth patient. This soldier had received 2,000 cc. of blood prior to performing a celiotomy and ligation of the superficial femoral artery. Following a transfusion of 500 cc. of blood administered postoperatively, he had a severe reaction and developed renal suppression, the result of hemoglobinuric nephrosis. Death occurred on the fourth postoperative day. The fifth patient sustained a severe crushing injury of the pelvis and right lower extremity, with dislocation of the right hip joint. In addition, a lacerated wound of the left arm had severed the brachial artery. As a result of the extensive crush injury, he developed a complete anuria and died on the fourth day after operation. The sixth death occurred from massive pulmonary embolism.

DISCUSSION.—From the data presented in Table I it is evident that the prognosis for survival of extremities in which major arteries are injured is not a good one. Subjecting the data to further analysis, we have studied the results as influenced by five important factors: (1) Time factor, *i.e.*, the interval between wounding and surgery; (2) type of arterial wound; (3) degree of tissue damage; (4) anatomic location of the arterial wound; and (5) influence of treatment.

(1) *Time Factor:* In Table III we have recorded the results as good or poor for extremity survival in relation to the time-interval between wounding and operation. It is obvious that those patients in whom definitive treatment could be instituted early (one to ten hours after wounding), had the best prognosis for survival of the extremity. There are, however, a number of

TABLE III
TIME FACTOR IN VASCULAR INJURY PROGNOSIS

	Time-interval between Wounding and Surgery	No. of Cases	Good Result	Poor Result
1.	One to 10 hours.....	31	21	10
2.	Ten to 20 hours.....	47	20	27
3.	More than 20 hours.....	22	5	17
	Totals.....	100	46	54

TABLE IV
INFLUENCE OF TYPE OF ARTERIAL INJURY ON PROGNOSIS

	Type of Arterial Wound	No. of Cases	Good Result	Poor Result
1.	Severed.....	68	25	43
2.	Laceration.....	17	10	7
3.	Incomplete laceration.....	3	3	0
4.	Laceration, with thrombosis.....	5	2	3
5.	Spasm.....	2	1	1
6.	Not determined.....	5	5	0
	Totals.....	100	46	54

circumstances which prevent early operation after the patient enters the hospital in addition to the unavoidable evacuation time from the field. Chief among these is the presence of severe shock from loss of blood. Obviously, it is better judgment first to consider saving the patient's life rather than his extremity when too early operation would be a great hazard. In addition, delays were unavoidable when a large number of high priority cases were admitted to the hospital within a short period of time. Ideally, the length of time between being wounded and operation should be reduced. This series represents a consecutive number of patients in which all the factors of evacuation surgery problems, from the finding of the patient on the field to preparing him to withstand operation, were present.

(2) *Type of Arterial Wound:* In Table IV the results in relation to the type of arterial wound are recorded. An accompanying wound of the vein in these early cases is not ordinarily significant from the standpoint of circulation. Arterial wounds have been classified as severed when the ends were completely separated. There were 68 in this group. Lacerated wounds were those in which any part of the circumference remained intact, preventing separation, and in this series there were 17. Incomplete laceration, of which there were three examples, was considered to be a wound which did not involve the intima. When a small laceration had extended through the intima, and thrombosis had occurred both proximally and distally, the fourth category

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was used. There were five cases of thrombosis. The type of injury was not determined in five cases which were not explored and arterial damage was inferred from the physical signs. In two cases of arterial spasm the arteries were visualized but no wound was discovered in them.

In Table IV it can be seen that, in general, the more severe arterial wounds resulted in a higher incidence of gangrene. Severed arteries resulted in 43 poor results out of a total of 68 cases. When the arteries were lacerated seven out of 17 resulted in loss of some part of the extremity. The degree of arterial damage was closely related to the tissue damage to the extremity.

(3) *Degree of Tissue Damage:* The effect of the severity of the wound on the circulation can be considered important from two aspects: First, because of the actual destruction of important radicles of the collateral anastomotic system; and, second, because of the systemic effect of shock and loss of blood.

The data listed in Table V indicates that the more extensive the tissue damage in the extremity, the poorer is the prognosis. In only nine of the 46

TABLE V
INFLUENCE OF DEGREE OF TISSUE DAMAGE ON VASCULAR INJURY PROGNOSIS

Degree of Tissue Damage	No. of Cases	Good Result	Poor Result
1. Slight.....	20	17	3
2. Moderate.....	38	20	18
3. Severe.....	42	9	33
Totals.....	100	46	54

good results was there severe tissue damage, while 33 of the 54 poor results showed a severe degree of tissue damage. In addition, in only 11, or 24 per cent, of the 46 good results was a compound fracture present, while 34, or 63 per cent, of the 54 poor results had coexisting fractures.

Other wounds of the same extremity distal to the arterial injury were present in two cases in which the extremities survived and in eight in which gangrene ensued.

The type of causative missile was recorded in each case as due to gunshot, shell fragment or knife. Shell fragment wounds include those from every type of explosive missile, *i.e.*, grenade, mine, aerial bomb, rocket and artillery shell. Two cases of knife wounds were treated, but there were no bayonet wounds. Sixty-four of the 100 wounds were caused by shell fragments and 34 by small arms missiles. Forty-six wounds were penetrating and 54 perforating in type. Neither the type of wound or the causative missile appeared to influence the result. The extent of damage to the tissues only was significant.

(4) *Anatomic Location of the Arterial Wound:* The clinical significance of the anatomic location of the arterial wound is related to collateral circulation, and for this reason a true picture of the significance of arterial severance at specific sites would require well-controlled experimental conditions. Since the time factor, degree of tissue damage, amount of blood loss, and degree of

destruction of collateral vessels are such variable factors in this study we can only arrive at the approximate significance of the anatomic site of the arterial wound. Therefore, the following figures, affected as they are by other variables, do not represent the incidence of gangrene after ligation alone.

In Table I it is obvious that wounds of the axillary and brachial arteries have a much better prognosis for survival of the extremities than wounds of the femoral and popliteal vessels. Twenty-seven of the extremities with brachial artery injury out of a total of 43 survived (63 per cent of the total). Of eight cases with axillary artery injury there were four extremities which survived (50 per cent of the total). On the other hand, only eight (29 per cent) of a total of 28 cases of injury of the femoral artery had an adequate circulation when they were transferred. Of 21 extremities with damaged popliteal arteries, seven (33 per cent) survived.

In order to arrive at some estimation of the comparative differences between arteries, insofar as the seriousness of injury to each of them is concerned, a study of those cases in which ligation was done gives the fairest picture. In Table I these figures are given. Ligation of the brachial artery resulted in the lowest incidence of gangrene and only 31 per cent of cases lost part of their extremity. Ligation of the axillary artery resulted in gangrene in 40 per cent of the cases. In the lower extremity, ligation of the popliteal artery resulted in gangrene of some portion of the leg in 77 per cent of cases, a slightly better figure than that obtained for ligations of the femoral artery (82 per cent).

The anatomic position of the wound in each artery was studied with a view to determining its significance in relation to the major collateral branches. In Table VI these results are listed.

Axillary Artery: In only four cases was the exact site of the axillary artery wound recorded. It was recorded as the third part of the artery in three cases, and all of these developed gangrene. The fourth patient in whom the site was recorded had a wound of the second part of the artery, and the extremity survived. No conclusions can be drawn from such a small number of cases other than the fact that in one-half of these patients gangrene of some part of the extremity ensued.

Brachial Artery: In injuries of the brachial artery it was possible to record the location of the wound in relation to the profunda branch but not in relation to the superior and inferior ulnar collateral branches. The latter two branches are small and it was not desirable to dissect them out for identification as a routine measure. The relation may be only inferred by the arbitrary division into proximal, middle and distal thirds of the portion of the brachial artery distal to the origin of the profunda branch. Wounds of the middle one-third probably did not involve either ulnar collateral artery. Wounds of the brachial artery appear to be most significant at one location—the origin of the profunda branch. The arterial wound involved both the brachial artery and the profunda branch in four patients, and only one arm survived. In two patients wounds destroyed the brachial artery and the

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proximal portions of the radial and ulnar arteries, and gangrene ensued in both cases. In both of these extensive tissue damage was present, and in one a primary amputation was performed. In the other, the wound was so extensive that little hope was held for its survival.

Femoral Artery: From Table VI it can be seen that gangrene resulted in all wounds of the common femoral artery, and also in two cases in which the

TABLE VI
INFLUENCE OF ANATOMIC LOCATION OF ARTERIAL WOUND ON PROGNOSIS

Anatomic Location of the Arterial Wound	No. of Cases	Good Results	Poor Results
1. Axillary artery:			
a. Second part.....	1	1	0
b. Third part.....	3	0	3
c. Location not stated.....	4	3	1
Totals.....	8	4	4
2. Brachial artery:			
a. Proximal to profunda branch.....	4	3	1
b. At origin of profunda branch.....	4	1	3
c. Distal to profunda branch:			
Proximal one-third.....	10	6	4
Middle one-third.....	13	9	4
Distal one-third.....	12	8	4
Totals.....	43	27	16
3. Femoral artery:			
a. Common femoral.....	5	0	5
b. At origin of profunda branch.....	2	0	2
c. Superficial femoral:			
Proximal half.....	9	3	6
Distal half.....	12	5	7
Totals.....	28	8	20
4. Popliteal artery:			
a. Involving the superior geniculate branches.....	7	0	7
b. Involving the inferior geniculate branches.....	6	0	6
c. Between the geniculate branches.....	4	3	1
d. Wound not explored.....	4	4	0
Totals.....	21	7	14
Totals.....	100	46	54

common femoral and the profunda branch were involved. However, the line of demarcation in three of the common femoral cases was observed to be at or below the ankle while the level of gangrene in extremities with superficial femoral artery injuries was usually half way between knee and ankle. The survival of eight extremities out of a total of 21 with wounds of the superficial femoral artery indicates the importance of the profunda branch in maintaining collateral circulation. Holman⁵ has stated that the blind segment of an artery between the site of ligation and the proximal major collateral branch acts detrimentally to the establishment of collateral circulation through that major branch. In our series the location of the wound in the superficial femoral artery was divided arbitrarily into proximal and distal halves with

the idea of determining the influence of this factor. In this series there were three (33 per cent) survivals in a total of nine wounds of the proximal half of the superficial femoral artery, and five viable extremities (42 per cent), resulting from a total of 12 wounds of the distal half of the artery. We would point out again, however, that the type of case with which we have experience has a number of complicating factors, because of the injury which make observations of this nature less reliable than in the case of elective operations for aneurysm and arteriovenous fistula.

Popliteal Artery: From Table VI it can be seen that in the seven cases in which either the superior or inferior geniculate branches of the popliteal artery were involved with the popliteal artery, gangrene ensued. Wounds of the midportion of the artery in which the geniculate branches were spared resulted in a survival of three extremities of a total of four. The four cases in which the wound was not explored might be added inferentially to the group without geniculate damage.

(5) *Influence of Treatment:* The principal accomplishment in these patients with major artery injury has been the saving of life by prompt and adequate treatment of shock and the prevention of serious infection by débridement. Gas gangrene either developed, or was present, in 12 of these avascular extremities, and three patients died from the infection. This complication was seen largely in patients received late in the hospital, and in those with multiple wounds of the extremity.

Arteriorrhaphy was useful in only a relatively few cases, since its application is limited by the extent of the wound.

Ligation of the artery with its companion vein, prevented secondary hemorrhage, of course, but contributed nothing to the survival of the extremity.

While lumbar sympathetic ganglion block with procaine had no appreciable effect in the majority of patients with severed arteries, it was of value in arterial spasm and should always be a part of treatment.

The results of the Blakemore nonsuture method of blood vessel anastomosis were disappointing, and, although the method has disadvantages which we have pointed out, the poor results may be attributed more properly to the lack of patency of the arterial system distal to the anastomosis.

The conservative management of arterial injuries employed in four patients with popliteal space hematomas cannot be recommended for wide application since the considerable hazard of gas-forming organisms is ever present. We have defined the narrow limits of application in our own series. It should never be employed for the avascular, cold extremity. We justified its use in four selected cases of clean, perforating bullet wounds of the popliteal space, with viable extremities, after having the experience of observing three similar cases result in gangrene after quadruple popliteal vessel ligation.

SUMMARY

Loss of some portion of the extremity by gangrene after arterial ligation had the following incidence, at our level of observation in the Forward Areas,

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in the arteries studied; axillary, 40 per cent; brachial, 31 per cent; femoral, 82 per cent; popliteal, 77 per cent; all arteries combined, 53 per cent.

For all types of arterial injuries, variously treated, the incidence of resulting impairment of circulation with loss of some portion of the extremity was as follows: Axillary artery, 50 per cent; brachial artery, 37 per cent; femoral artery, 71 per cent; popliteal artery, 67 per cent.

The prognosis for extremity survival in relation to the time factor, arterial wound, extremity wound, anatomic site of arterial injury, and treatment have been discussed.

Six deaths occurred among the 100 patients with injuries of major arteries in the Evacuation Hospital. Infection with gas-forming organisms resulted in 12 patients, of whom three died, accounting for one-half of the deaths in the series.

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PENETRATING HEAD WOUNDS

EXPERIENCES FROM THE ITALIAN CAMPAIGN

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DURING THE PAST YEAR of the Italian campaign 140 penetrating wounds of the head, upon whom craniotomy had been performed, were cared for in an Evacuation Hospital. This series of consecutive cases, though essentially similar in their pathology, may roughly be divided into three groups relative of the tactical situation during which they were treated.

Within the period of the Anzio beachhead 53 cases were seen, and all within 24 hours of their injury. Because of the size of the beachhead, distance from the lines to the Evacuation Hospital was short. The patients were all soldiers, and for tactical reasons were evacuated as soon as possible. Chemotherapy consisted entirely of the sulfa drugs.

As the front moved up in Italy from the Garigliano River toward the Gothic Line a second group of 45 cases was treated. The Evacuation Hospital was then well out of range of shell fire and cases reached the hospital somewhat more slowly. There were seven injured civilians in this group. During the latter half of this period penicillin became available for all cases.

The last group of 42 cases was treated when the hospital was situated near the lines but out of range of shell fire. These cases were seen comparatively early and, as with the second group, the tactical situation did not necessitate their evacuation until it was deemed they were well able to travel—in contradistinction to the cases at Anzio. In this last group penicillin as a chemotherapeutic agent was used exclusively. The group was composed entirely of soldiers injured in penetrating and pushing on through the Gothic Line.

An analysis of these three groups forms the subject of this report.

I. *Source of Casualties:* Ninety per cent of all injuries were caused by shell fragments. The large preponderance of these was the result of artillery or mortar fire while a few resulted from fragments of antipersonnel bombs, mines and booby traps. Five per cent of all casualties were gunshot wounds (rifle, machine gun, or pistol). The remaining 5 per cent were attributed to injuries sustained in jeep accidents, falls, a knife wound and the recoil of a breech block.

With the exception of the civilians the age of the patients varied from 18 to 38 years, the mean falling at 24 years. The ages of the civilians ranged from 34 to 56 years.

II. *Evacuation Time:* Table I is included to show the time-interval between injury and surgery. The average time from wounding to surgery was 14 hours at the Anzio beachhead, while 31 hours was the average elapsed time for cases during the Garigliano-Gothic Line phase. If one excluded two cases received eight and 13 days after injury the average in this group is reduced to 21 hours.

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III. *Preoperative Findings:* The anatomic location of the various wounds is illustrated in Figure 1.

The most common type of scalp wound seen was a jagged laceration, varying in length from 1 cm. to 12 cm. Almost as frequent were puncture wounds. Occasionally a "through-and-through" injury was encountered in which the more massive damage always occurred at the site of the exit.

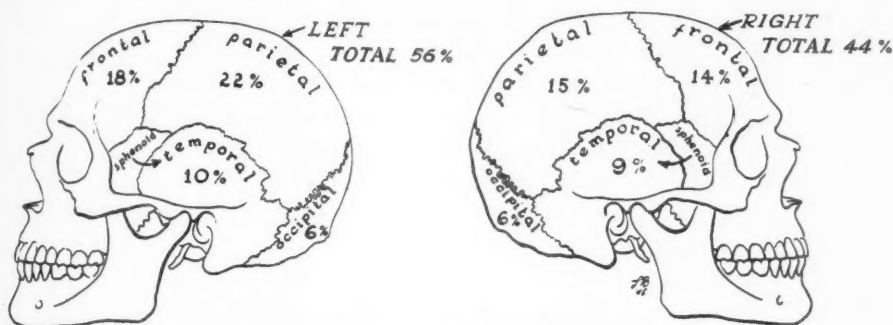


FIG. 1.—Showing the anatomic location of the various wounds.

The exact figure concerning the number of men wounded while wearing their protective helmet is not available. This is partly due to retrograde amnesia caused by the injury and to the fact that the helmet, although worn, was occasionally blown off the head by the shell blast. About half the men claimed to have been wearing their helmets when they were wounded.

Twelve per cent of the patients were admitted in shock. In two-thirds, shock was attributed directly to the head wound while in the other one-third shock was due to associated injuries, particularly of the long bones. Thirty-six per cent of the patients had associated injuries of varying degrees of severity.

Seventy-eight per cent of the patients were conscious at the time of examination. Monoplegia or hemiplegia was found in 20 per cent of all cases, while hemiparesis was noted in 8 per cent. Aphasia was present in 11 per cent of the cases, and 4 per cent had homonymous hemianopsia. More significant was the presence of a decerebrate type of rigidity in 4 per cent of the patients, all of whom died. Half of the 6 per cent of patients incontinent on admission expired. Though the Babinski sign was found in 17 per cent of the cases it seemed to have little prognostic significance.

Almost half of all of these head injuries (43 per cent) had some degree of brain tissue herniating through the wound. Brain hernia was seen only one-fifth as often in puncture wounds as in all other types. Twenty-three per cent of those patients with brain hernia died.

Roentgenograms of the skull revealed intracranial foreign bodies in 53 per cent of the cases, while 43 per cent had indriven bone fragments. Depression of one or both tables of the skull was noted in 49 per cent of cases. Stellate-type fracture was seen in 14 per cent of the cases, and "bursting" fractures were described in 3 per cent. The air sinuses were found to be compounded in 10 per cent of all cases.

IV. *Preoperative Therapy*: Treatment at stations prior to the Evacuation Hospital was largely supportive in character. The patients' wounds were dusted with sulfa powder and a protective head dressing was applied. A stimulating dose of tetanus toxoid was also administered. One-third of the patients required an analgesic and/or sedative, after injury. Morphine, 0.25 gr., was usually administered, being given at the more forward installations. It was seldom necessary to repeat the dose. Half of the patients received plasma, and the average case was given 2.6 units.* One patient in every five required transfusion of whole blood. The maximum amount of blood given was 2,500 cc., and the average amount was 950 cc.

V. *Anesthesia*: It was possible, with the cooperation of the patient, to carry out the procedure under local anesthesia in 64 per cent of the cases. Procaine, 1 per cent, was used. Sodium pentothal, in conjunction with local anesthesia, was employed in 26 per cent of the patients. This combination had its greatest usefulness in the restless, apprehensive patient, or those upon whom other minor débridements were to be undertaken concomitantly. Gas-oxygen-ether was given to 8 per cent of the cases, and this included the group of major complicating injuries or penetrating head wounds with extensive maxillofacial injury. The remaining 2 per cent of the cases were so deeply comatose that no anesthesia was required.

VI. *Surgery*: The average duration of an operation was one hour and forty minutes. Various aspects of the procedure have been subdivided according to the structures encountered.

(a) *Scalp*.—It was found feasible to effect an elliptical excision of most scalp wounds, since the majority of wounds were roughly linear or were puncture wounds. Where a jagged stellate defect existed only the wound edges were excised, in order to preserve all available tissue for closure. In three instances it was necessary to slide a flap of scalp in order to close the defect, the donor site then being covered with split-thickness skin graft.

(b) *Bone*.—In general, a circular or an ovoid bony defect was encountered. The average circular defect measured 2 cm. in diameter, while the ovoid-shaped defects averaged 2.1 cm. x 4.5 cm. in their narrowest and longest diameters, respectively. Procedure in the usual case was to enlarge the bony defect with rongeurs to obtain clean bone edges and normal dura about the periphery of the defect. By so doing the measurements of the defect were roughly doubled.

Fracture involving the air sinuses, and similarly the orbit, was found in 17 per cent of the cases. The practice of stripping the mucous membrane from the sinus walls was followed out, though in no instance was evidence of sinus infection noted.

(c) *Dura*.—Laceration of the dura was found in 77 per cent of the cases. These dural tears were usually linear in character, and varied in length from 0.5 cm. to 12 cm. Three-fourths of all lacerations averaged 2.3 cm. Multiple dural penetrations occurred in one-sixth of these cases. With more massive

*One unit of dried plasma represents the plasma component of 500 cc. of whole human blood.

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injuries, dural defects of sizes varying from 2 cm. x 3 cm. up to 5 cm. x 8 cm., were found. Because the dura was rarely found to be grossly contaminated, débridement was confined to excising only the frayed edges of the membrane. In the remaining 23 per cent of cases in which intact dura was found, the membrane was usually tense and less frequently discolored and nonpulsating. Here the dura was opened sufficiently to explore for subdural or intracortical fluid or clot.

Though epidural bleeding was noted in 12 per cent of the cases, in no case was the accumulation felt to be large enough to be of clinical significance. Subdural accumulations of blood or clot were found in a similar frequency, but in half of these cases the volume measured from 40 cc. to 150 cc., and was considered of clinical significance.

Injury to the intracranial venous sinuses and partitioning structures (falx cerebri and tentorium cerebelli) occurred with equal frequency (6 per cent of the cases).

(d) *Brain*.—The paths of most foreign bodies and/or bone fragments through the cortical substance created tracts which usually were roughly cylindrical in shape, though some were conical and fewer were shallow craters of the brain substance. Tracts varied in length from 2 cm. to 17 cm., the average being 8.1 cm. Aspiration, by suction and irrigation, of the pulped cortical tissue and clots found along the tract produced a tunnel through the brain along the sides of which was found a thrombosed plexus of cortical vessels, apparently the supporting vascular frame work for that area of the brain prior to injury. Where a foreign body and bone fragments were found intracortically the foreign body was always at the deepest portion of the tract. An effort was made to dislodge both bone fragments and foreign bodies by irrigation or under direct vision. In narrow or deep tracts where metallic foreign bodies could not be visualized, their removal was attempted by gently contacting them with a magnet. This was successful in about half of the cases. Where feasible, finger exploration of the débrided brain tract was undertaken, frequently revealing retained bone fragments or pockets of incompletely débrided soft brain tissue.

As has been noted, there was roentgenographic evidence of intracranial foreign body in 53 per cent of all cases. Sixty per cent of these were removed surgically. On the other hand, roentgenograms revealed evidence of indriven bone fragments in 43 per cent of all cases, but bone chips were removed from the brain in 57 per cent of all cases.

Seventy-nine per cent of all tracts were unilateral, and 21 per cent were bilateral. Tracts crossing the midline were found to be twice as fatal as others. The ventricular system was found to have been compounded in 20 per cent of the cases, and of these 35 per cent terminated fatally.

(e) *Repair*.—In the group of cases operated upon at the Anzio beachhead it was generally the policy to introduce sulfa powder into the wound. This was sprinkled lightly into the brain tract in three-fifths of the cases and along the scalp wound in another fifth. This practice was discontinued in the subse-

quent group of cases and no local chemotherapy was used until penicillin became available. In roughly the last half of the cases of the entire series, 10,000 units of penicillin in 2 cc.—5 cc. of distilled water was introduced into the brain cavity.

Tight primary closure of the dural wound was possible in over half of all cases. In an additional 7 per cent of cases a tight closure was effected through the employment of grafts, using either pericranium or fascia lata. This procedure was thought imperative in compound wounds of the ventricles. In

TABLE I
TIME-INTERVAL BETWEEN INJURY AND SURGERY

Time-interval	Garigliano-Gothic	
	Anzio	Line
0-4 hours.....	2	0
4-8 hours.....	7	6
8-12 hours.....	13	8
12-18 hours.....	14	11
18-24 hours.....	10	6
24-48 hours.....	5	7
Unknown.....	2	
Over 2 days.....		2
Over 3 days.....		2
Over 4 days.....		1
Over 8 days.....		1
Over 13 days.....		1

30 per cent of the dural wounds the edges could be approximated but no tight closure secured. In the remaining 12 per cent of the cases no closure was attempted. This includes a small number of cases in which a subtemporal decompression was left, or where surgically inaccessible lacerations were bridged by adjacent structures. For example, linear tears of the inferior surface of the frontal lobes were frequently associated with comminution of the superior plate of the orbit and laceration of the periosteum of the orbit. Here, herniation of the retro-orbital fat against the torn dural edges seemed to effect a satisfactory closure.

Two-layer scalp closure was undertaken except in those occasional cases where, due to the precarious state of the patient, a single-layer scalp closure was made to save time. In 60 per cent of the first group of cases a small Penrose drain down to the dura was placed for a 24-hour period. This practice was discontinued in the latter two groups of the series.

VII. Postoperative Treatment: The first half of the patients in this series received sulfathiazole or sulfadiazine as a postoperative routine. When penicillin became available this regimen was discontinued. The patients in the second half of the series got 25,000 units of penicillin intramuscularly every three hours for at least five days. Lumbar puncture, blood and plasma were used when deemed necessary. Patients were given fluids and food by mouth and encouraged to become ambulatory as soon as possible. Though it was necessary, for tactical reasons, to evacuate the average patient in the Anzio group on the fourth postoperative day, cases in the latter two groups could be held for a week or longer before being sent back to Base Installations.

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TABLE II.—SUMMARY OF DATA IN 24 FATALITIES.

1	2	3	4	5	6	7	8	9	10
NO.	REG- ION IN- VOL- ED*	ADDI- TIONAL IN- JURY	TIME- HRS. INJ- SURG	NEUROLOGIC FINDINGS	CR- OSS MID LINE	COM- P.D. VEN- TRI- CLE	POSTOPERATIVE COURSE	DAY DIED POST- OP.	AUTOPSY
1	R.O.	ABD., CHEST.	7	NEGATIVE, CONSCIOUS	0	+	HYPERTHERMIA	3	BASAL SOFTENING ABOUT TRACT
2	L.F.	EYE	15	CONSCIOUS — B.P. 160/80	+	0	INCREASING HYPERTENSION, HYPERTHERMIA	1	DIENCEPHALIC PETECHIAE, BLAST INJURY OF LUNGS, KIDNEY.
3	R.F.P.	0	9	COMA; HYPERPNEA; RT. EXTENSOR RIGIDITY; IN- CONJUGATE E.O.M.; INCONT.	0	0	DECEREBRATE RIGIDITY	3	NO TIME TO DO AUTOPSY
4	L.F.P.	0	31	COMA; L. HEMIPLEGIA; HYPER- PNEA; INCONTINENT; BILAT. BABINSKI; INTERMITTENT SPASM	0	+	DECEREBRATE RIGIDITY HYPERTHERMIA	3	NO TIME TO DO AUTOPSY
5	L.T.	0	35	COMA; INCONTINENT; RESPIR- STERTOR; DECEREB. RIGIDITY BILATERAL BABINSKI	+	0	DEEP COMA INCONTINENT	2	PETECHIAE ABOUT TRACT, MULTIPLE CONTUSIONS
6	L.P.	0	12	COMA; PULSE 150; BILAT. HY- PERREFLEXIA & TONICITY; RIGHT BABINSKI	0	0	HYPERPNEA HYPERTHERMIA	1/2	BASAL NUCLEAR SOFTEN- INGS AND PETECHIAE
7	L.F.	MULTIPLE PEN. WDS COLOSTOMY FCC FEMUR	22	DROWSY; OTHERWISE NEURO. NEGATIVE	0	0	DOING WELL UNTIL DIED SUDDENLY	7	SMALL SOFTENINGS ABOUT TRACT; INSUFFICIENT TO CAUSE DEATH; REASON OBSCURE.
8	R.SUB OCCIP.	FCC HUM- ERUS WOUNDS OF THIGH	13	DROWSY; PROJECTILE VOMITING; NEURO. NEG.	+	+	IRRATIONAL EXPIRED SUDDENLY	1	SOFTENING, LACERATION OF CEREBELLAR LOBES. INTERNAL HYDROCEPHALUS
9	L.P.	MAL- ARIA	12	COMA; STERTOR-RESPIRATION L. HEMIPLEGIA; BABINSKI L. HOFFMAN; DILATED FIXED PUPILS	0	0	RAPIDLY DOWNHILL	1	DIFFUSE SUBDURAL & SUBARACH. HEMORRHAGE; MULTIPLE PETE- CHIAE MESENCEPHALON
10	R.O.P.	HEAD WOUND. INFECTED ON ADMN.	80	SEMICOMATOSE; RESTLESS; WOUND PURULENT	0	0	REMAINED COMATOSE	2	INFECTION LOCALIZED EXTRA- DURALLY; CEREBRAL SOFTENING MESENCEPHALIC HEMORRHAGE
11	R.T.P.	HEAD & ARMS INFECTED ON ADMN	96	COMA; SHOCK; TOXIC DEHYDRATED	+	+	RAPIDLY DOWNHILL PENICILLIN	1/2	ACUTE FULMINATING CEREBRITIS; MENINGITIS
12	L.T.	LAC. WD. ARMS	8	COMA; HYPERACTIVE LEFT DEEP REFLEXES; BABINSKI LEFT HEMIPLEGIA	+	+	DROWSY; HYPERPNEA HYPERTHERMIA.	3	SOFTENING (BASAL) ALONG TRACT
13	R.T.P.	0	12	DEEP COMA; BLOOD IN RT. EXT. EAR; L. BABINSKI; ECCHY- MOSIS OF RIGHT EYE	0	0	COMA; HYPERPNEA HYPERTHERMIA	1	CORTICAL CONTUSION, EXTENSIVE SKULL FRACTURE, SUBARACHNOID HEMORRHAGE
14	L.T.	0	9	COMA; LT. ANKLE CLONUS SPASTIC QUADRIPLEGIA BILAT. BABINSKI	+	0	COMA HYPERTHERMIA	1	AUTOPSY NOT DONE
15	L.P.	SHOCK	6	RT. HEMIPLEGIA; HYPERPNEA, RT. AREFLEXIA	0	+	REMAINED COMA, HYPERTHERMIA	3	AUTOPSY NOT DONE
16	R.F.T.	0	10	COMA LT. HEMIPLEGIA	0	+	HYPERPNEA HYPERTHERMIA	1	AUTOPSY NOT DONE
17	L.T.	SHOCK	54	COMA; CHEYNE-STOKES BILATERAL BABINSKI DECEREBRATE RIGIDITY	0	0	HYPERPNEA HYPERTHERMIA	3	MULTIPLE PETECHIAL HEM. BASAL SOFTENINGS HEMORRHAGE
18	L.P.	0	12	DEEP COMA; STERTOROUS RESP. HYPERTHERMIA	0	+	CONTINUED COMATOSE	1	EXTENSIVE CEREBRAL THROMBOSIS ABOUT TRACT
19	R.P.	0	14	COMA; VOMITING; RIGHT HEMIPLEGIA LEFT BABINSKI	0	0	RESPONDED TO SURGERY—LATER COMA & HYPERPNEA	3	ENCEPHALOMALACIA, PARIETAL LOBE, LEFT, WITH CORTICAL LACERATION & HEMORRHAGE
20	L.T.	0	3	IRREGULAR RESP. COMA; BILATERAL ATONIA FIXED PUPILS	+	0	PULSE BECAME IMPERCEPTIBLE AT SURGERY	1/2	BASAL SKULL FRACTURE; SUBARACH- NOID HEM; BASAL CISTERN PETE- CHIAE, DIEN. & MESENCEPHALON
21	L.T.	MULT. PEN. WDS.	15	SEMICOMA; SHOCK; APHASIA RT. HEMIPLEGIA, BABINSKI	0	+	COMA; HYPERPNEA HYPERTHERMIA	1	AUTOPSY NOT DONE
22	L.P.	0	27	SEMICOMA; IRRITABLE; IN- VOLUNTARY; MODERATE BILAT. EXT'R. RIGIDITY; BILAT. BABINSKI	+	+	COMATOSE HYPERTHERMIA	2	BILAT. ENCEPHALOMALACIA OF PARIETAL LOBES ABOUT TRACT.
23	L.F.	PEN. WDS. ABD. LEGS	24	SEMICOMA; APHASIA RT. HEMIPLEGIA	+	+	DEVELOPED INT. HYDROCEPHALUS	3	BLEEDING INTO BASAL CISTERN CLOT IN AQUEDUCT OF SYLVIIUS PETECHIAE ABOUT TRACT
24	L.P.	0	12	COMA; RT. BABINSKI; HEMI- PLEGIA; HYPERTONIA AND HYPERREFLEXIA	0	+	DID NOT RESPOND HYPERTHERMIA HYPERPNEA	3	BASAL SKULL FRACTURE; INTRA- VENTRICULAR BLEEDING; PETE- CHIAL L. FRONT. & TEMP. LOBES

* KEY: R—right; L—left; p—parietal; o—occipital; T—temporal; F—frontal

TABLE III.—BRIEF ANALYSIS OF 16 CASES IN WHOM INFECTION WAS PRESENT.

HOURS IN J. TO SURG.	INFECTED ON AD- MISSION	COM- POUND SINUS, EAR, ETC.	FOREIGN BODY PRESENT	FOREIGN BODY REMOVED	BONE FRAG- MENT PRESENT	BONE FRAG- MENT REMOVED	DURAL REPAIR	DRAIN TO DURA	CHEMOTHERAPY			INFECTIONS	RESULT
									TRACT	SCALP	SYS- TEM- IC		
29	0	0	0	0	+	+	FASCIA LATA GRAFT	+	0	+	S	BRAIN ABSCESS	IMPROVED
26	0	0	0	0	0	0	CLOSED	0	0	+	S	SCALP ONLY	WELL
14	0	0	+	+	+	+	APPROX.	+	+	0	S	ABSCESS, MENINGITIS	DIED
15	0	0	0	0	+	+	APPROX.	+	+	+	S	SMALL ABSCESS	WELL
27	0	0	+	+	+	+	CLOSED	+	+	0	S	SCALP ONLY	WELL
24	0	EXTERNAL EAR	+	0	0	0	NOT CLOSED (DECOMP.)	0	+	0	S	ABSCESS	DIED
18	0	0	0	0	+	+	CLOSED	+	+	0	S	ABSCESS	IMPROVED
8	0	FRONTAL SINUS, ORBIT	0	0	+	+	CLOSED	+	+	0	S	CEREBRITIS, ABSCESS	UNIM- PROVED
80	CELLULITIS OF SCALP, SKULL, ORBIT	0	0	0	0	0	INTACT, C PULLEN WOUND, PACKED OPEN	WOUND PACKED OPEN	0	PENI- CILLIN	P	INFECTION LOCALIZED EXTRADURALLY	DIED— NEUROGENIC DEATH
96	FULMINATING CEREBRITIS	0	+	0	+	0	WOUND, PACKED OPEN	0	+	0	P	FULMINATING CEREBRITIS & MENINGITIS	DIED
24	0	0	0	0	+	+	CLOSED	+	0	0	P	SCALP ONLY	WELL
200	CELLULITIS SCALP LOCAL OSTEO. OF SKULL THICKENING DURA	0	0	0	0	0	INTACT	WOUND PACKED OPEN	0	PENI- CILLIN	P	INFECTION LOCALIZED EXTRADURALLY	IMPROVED
19	0	MASTOID CELLS	0	0	+	+	CLOSED	0	0	0	P	SMALL ABSCESS	IMPROVED
320	LOCALIZED DRAINING BRAB- SCES & OSTEO	FRONTAL SINUS	0	0	+	+	LEFT OPEN	WOUND PACKED OPEN	PENICILLIN WICK	0	P	LOCALIZED DRAINING BRAIN ABSCESS	IMPROVED
17	0	0	+	+	+	+	CLOSED	0	+	0	P	BRAIN ABSCESS	IMPROVED
20	0	0	+	+	+	+	CLOSED	0	+	0	P	CEREBRITIS, MILD— DID NOT REQUIRE SURGERY	WELL

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VIII. *Deaths*: There were 24 fatalities in this series, a mortality of 17 per cent. Analysis of these deaths appears in Table II.

IX. *Disposition*: Of the 116 patients evacuated from this hospital all were sent to General Hospitals in the rear, except for seven Italian civilians who were placed in civilian hospitals. These civilians were held at our hospital until such periods in their convalescence that we felt they were past the hazard of infection, since civilian hospitals at this time were frequently not equipped to undertake neurosurgery. In the group of 109 military patients it was possible to obtain follow-up data on 103. Records of the other six cases are still incomplete. Of the followed cases, 16 per cent were returned to duty, while 84 per cent were sent to the Zone of Interior (United States) after varying periods of recovery in Base Section General Hospitals. The most pertinent problems in this followed group seemed to be those of infection and the necessity of reoperation. Full neurologic recovery had not been made by most patients. Table III is a brief analysis of the 16 patients in whom infection was present. These are listed chronologically. Discussion of this data is reserved for a later section of this paper.

It was found necessary to perform a secondary craniotomy upon 18 patients at General Hospitals. Eight of these patients had brain abscesses. Table IV is a summary of these secondary operations performed for residual non-infectious disease.

COMMENT: The Evacuation Hospital is the unit in the Italian campaign where the large majority of penetrating head wounds underwent definitive surgery. When a great influx of casualties occurred it was found necessary to establish some system of priority for surgery. It soon became evident that certain patients with head wounds would probably not survive intervention. In this category were those in deep coma, with stertorous breathing, a rapid pulse, and low blood pressure, and who exhibited such neurologic signs as decerebrate-type of rigidity, fixed unequal pupils and involuntary micturition. Because they tended to develop pulmonary edema, frequent aspiration of the pharynx and trachea was necessary. They were given whole blood and concentrated solutions of plasma but usually continued to go downhill. Less severely wounded men usually improved after such a regimen. It was the patient who, despite a rapid pulse, initially low blood pressure, and marked neurologic signs, tended to improve that we felt warranted priority surgery. In none of these cases, however, was surgery undertaken as an emergency measure. Though it was occasionally necessary to control a scalp bleeder with a clamp or a ligature, it was thought that patients generally withstood surgery better if given adequate opportunity for stabilization of their vital signs.

It is curious to note that 12 per cent more injuries occurred on the left rather than the right side of the head. This ratio has remained constant through the various groups comprising the entire series. One can only speculate as to an explanation. It is conceivable that since soldiers are predominantly right-handed, they are somewhat more alert to danger on their right. Likewise, one can but theorize as to the value of the protective helmet from these statistics. Assuming equal protection over the head, the fact that

the temporal and occipital regions are less frequently wounded could be explained by their relatively smaller surface area but, more significantly, more basal injuries are most lethal and probably never reach the Evacuation Hospital.

TABLE IV

SUMMARY OF DATA UPON 18 CASES REQUIRING SECONDARY CRANIOTOMY FOR RESIDUAL NONINFECTIOUS DISEASE

Preoperative Diagnosis	Findings	Result
1. Intracortical hematoma	Soft brain, clot along tract	Improved
2. Intracortical mass lesion	Subdural hematoma; softening along tract	Improved
3. Intraventricular bone fragments	Fragments removed; noninfected	Well
4. Subdural hematoma?	Negative exploration	Improving
5. Brain fungus	Fungus resected; primary closure	Well
6. Intracranial mass lesion	Bilateral subdural hematoma (missed on primary exploration for hematoma)	Improved
7. Subdural hematoma?	Small epidural hematoma	Well
8. Intracortical foreign body	Foreign body not found	Unimproved
9. Intracranial mass lesion	Intracortical hematoma	Improved
10. C.S.F. rhinorrhea	Repair of dural tear	Well

Because one in three patients exhibits some measure of paralysis, aphasia or hemianopsia, a philosophy of adequate but not necessarily radical débridement was adopted. Devitalized, contaminated bone was resected, but not "*en bloc*." Every effort was made to remove all bone fragments and pulped brain tissue from the tract because of their known tendency to produce abscesses. Small shell fragments, on the other hand, were frequently left *in situ* since they were much less likely to harbor infection. Surgically inaccessible lesions, previously referred to, should be construed as those whose repair might require more extensive surgery than the nature of the lesion itself would justify. This principle is equally applicable to certain deeply situated small shell fragments.

Of the 103 soldiers on whom follow-up data was available 11.6 per cent subsequently developed some form of infection. It may be of interest to examine more closely the various factors which might explain the difference between an incidence of 21 per cent infection of the cases operated upon on the Anzio beachhead and 5.7 per cent of the cases resulting from the Gothic Line push. The time-interval between wounding and surgery was slightly longer in these infected cases. The fact that a missile traversed the air sinuses, orbit, external ear or mastoid cells on its path into the cranium did not seem to enhance the likelihood of any particular case becoming infected. Likewise, a metallic foreign body left *in situ* did not seem to increase the incidence of sepsis. Bone fragments are seen less frequently roentgenographically than they are found surgically. It is, therefore, not unlikely that other smaller fragments are missed at operation. In several instances small fragments, missed at primary débridement, were later found when a brain abscess was drained. On the other hand, retained bone fragments were the indication for secondary craniotomy in another case, and were noninfected when removed from the wall of the lateral ventricle. For this reason, whether they act as a nidus of infection cannot be definitely ascertained in any particular case. There seems to be no relation between the type of dural repair and likelihood

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of subsequent sepsis. In 60 per cent of the cases operated upon at Anzio a small Penrose drain was placed down to the dura. One in five of these patients developed infection. It became evident when these cases were seen in General Hospitals several months later that the use of the drain did not prevent infection and may have contributed to it. Its use was discontinued except in the occasional case.

As has been stated, during the phase of the Anzio beachhead the sulfa drugs were used chemotherapeutically, whereas only penicillin was used in the most recent (Gothic Line) phase. There were almost four times as many infections in the former group. Any improvement, however, cannot be directly attributable to a change in chemotherapy alone, since the practice of draining was discontinued and because, for tactical reasons, it was possible to hold this latter group until wound healing was more complete before evacuation.

A mortality of 17 per cent has characterized all groups of the entire series. This would seem to vary almost directly with the tactical situation. When time is not a factor there is a tendency to attempt surgery upon patients whom one feels may have been doomed since wounding. During a great influx of patients priority must be given to those who have a reasonable chance to survive. Time was not always available to perform postmortem examination. On gross examination of 18 brains removed at autopsy, death was due directly to the effects of brain injury, except for one case who died of a fulminating cerebritis present on admission.

SUMMARY

A consecutive series of 140 cases of penetrating wounds of the head sustained during the past year of the Italian campaign is presented. Craniotomy was performed upon these patients at an Evacuation Hospital. Thorough but not extensive débridement was attempted. Penicillin seemed more efficacious as a chemotherapeutic agent than the sulfa drugs in this series.

TREATMENT OF JAW AND FACE CASUALTIES IN THE BRITISH ARMY

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FROM A BRITISH ARMY MAXILLOFACIAL SURGICAL UNIT.

THIS ACCOUNT of the treatment and results of 1,000 jaw casualties* is made with special reference to the fixation of the bone fragments and the early repair of the soft tissues. An attempt is made to compare the methods of treatment in British and American Armies. The work was done in North Africa and Italy. In both countries this Unit came in frequent contact with the maxillofacial services of the United States and of the French Armies. The Unit landed in North Africa with the First Army in November, 1942. In the early part of the Tunisian Campaign it shared in the early treatment of American as well as British casualties. Subsequently, in Italy, it had the late care of many British casualties who had had their primary treatment in American hospitals.

In North Africa all British M. F. casualties were concentrated in the one Center at Algiers. The early treatment was done by Forward general surgeons, as was the case with the Eighth Army M. F. casualties in the Desert campaigns. The policy of concentrating all M. F. cases was extended in Italy where, at Naples, this Unit was responsible for the treatment of the British M. F. casualties from the battles and combined operations on the west coast. Working in the facilities of a General Hospital 50 miles from a static Front, it was able to develop the surgery of the soft tissues and in particular to explore the scope of primary suture in battle wounds of the face. After Cassino, when the Armies advanced along the peninsula, the system of concentrating M. F. casualties into one Forward Unit continued. The Unit provided a Forward Section which was equipped to do full facial repairs, and was able to hold its cases for three to five days before evacuating them by air to its own Main Section at Naples. This Forward Section was placed together with Special Head and Special Eye Units, at a Forward Hospital, or C. C. S., so that casualties reached it in six to 30 hours. A most successful system of *triage* assured that all British head, eye, face and jaw (and most pharyngeal) wounds arrived at the Forward Hospital to which these three special units were attached. This system, rather than the alternative of having individual specialists attached to general units, was a success because: the early forward sorting was very efficient; special equipment in generous

* Cases treated up to November, 1944.

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quantities had been concentrated at these special units; and distribution of personnel and equipment between Forward and Main Sections of the Maxillofacial Unit was left a Unit responsibility by higher administration; it was thus possible for changes to be made easily and quickly to meet the varying demands of the two Sections.

The work of the Main Section at Base has been the intermediate care and the late repairs. The number and extent of late repairs has depended on the number of hospital ships and on the pressure of work. In practice, nearly every case has been held one to two months; many whose total period of incapacity has been four to seven months have been seen through to union of the jaw, correction of their facial deformity, and return to duty in the Mediterranean. Of 1,000 jaw fractures* described here, 600 returned to duty in the Mediterranean; 400 were evacuated to the United Kingdom healed after one to two months treatment at Main Section of the Unit.

Split into Forward and Main Sections a single M. F. Unit has the opportunity—rare in the Army—of being able to follow its cases through from Forward surgery to return to duty, and of being able to correlate both aspects, early and late, of military M. F. work.

The Maxillofacial Casualty.—This paper is concerned only with the casualty who has a jaw fracture. Seven hundred of the 1,000 cases were missile wounds. Forty per cent of these were due to mortar; nearly 30 per cent each to shell and bullet and less than 5 per cent each to grenade mine and bomb. These 700 missile wounds include 50 each of associated major pharynx and palate wounds.

Three hundred cases were closed injuries and were chiefly caused by vehicle accidents including battle accidents; a third of the closed injuries were due to brawls.

A typical missile fracture of the jaw shows gross comminution with involvement of an indeterminate number of teeth and scattering of bone and tooth fragments into surrounding soft tissues. The track of the missile commonly penetrates tongue and pharynx and may lead towards the cervical spine across the carotid sheath.

The missile which traverses the maxillary block often destroys the eye and disorganizes antrum and palate. If it is a large missile the whole block may be "floating" with gross malocclusion, and comminution may involve ethmoid and sphenoidal sinuses and the floor of the anterior cranial fossa. There is a high incidence of associated brain injury, and death from this and from respiratory complication is relatively common compared to mandibular wounds.

TREATMENT OF THE MAXILLOFACIAL CASUALTY

Treatment of the maxillofacial casualty falls into three phases: early, intermediate, and late. The less that is done at the primary treatment the more extensive and prolonged are the intermediate and late phases.

For the greater part of this war the early treatment of maxillofacial

* In 4,600 casualties (maxillofacial, burns, and body plastics) treated in 2.5 years.

casualties in the British Army consisted chiefly of dental fixation. Repair of soft tissues was left until after natural healing, with deformity. This treatment led to prolonged hospitalization for even minor facial wounds. Conservation of dead bone and soft tissues caused a high incidence of infective complications. The treatment described here has been the routine for the casualties in Italy. It was evolved as a result of experience in North Africa, when ample opportunity of seeing the results of conservative early surgery was afforded the Unit in Algiers.

EARLY TREATMENT

1. *Soft Tissues*.—A primary closure of a face wound is more often possible and safe than it is in most other sites. The tracks of many of the missiles

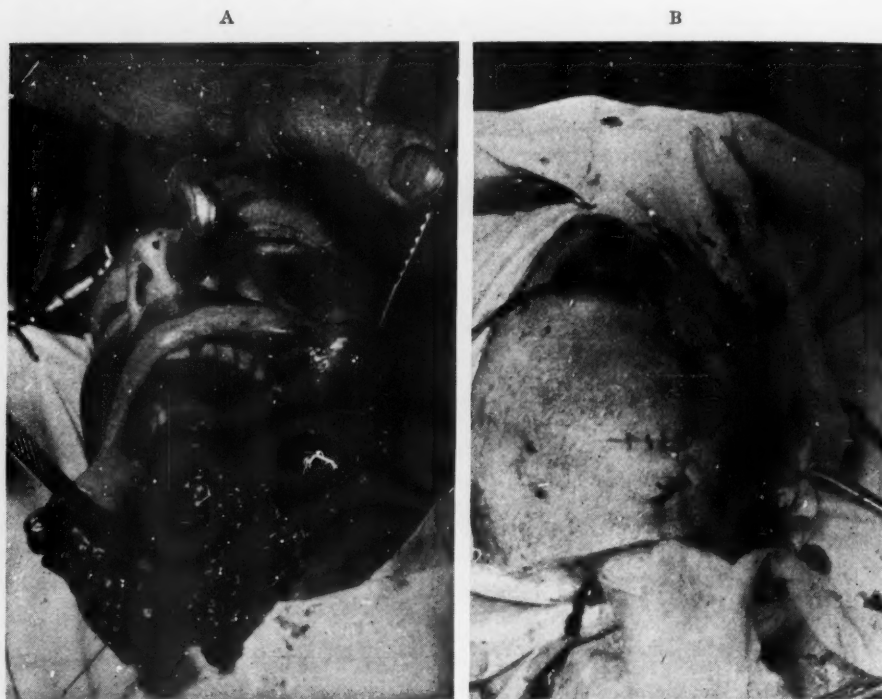


FIG. 1.—Primary soft tissue repair of major mandibular wound with gross bone loss:
A. Disruptive wound six hours old.
B. The same after clearance of bone fragments, soft tissue excision and closure. The drain was out and healing complete at ten days.

are capable of thorough excision, and the free blood supply ensures a maximum survival of damaged tissues. The surgeon must be certain that he can hold his cases three to five days and supervise removal of his own sutures. Under the right conditions primary closures not only shorten healing times drastically, to the great relief of the patients, but diminish the incidence of bone infection. Whenever possible the jaw should be fixed at the same operation. If splints have to be used it is usually wise to accept the six to eight hours delay necessary for their construction. About 20–30 per cent of maxillofacial missile wounds are suitable for primary final repairs.

These primary repairs are done when the wound looks clean, is under 24-36 hours old, and the tissue loss is such that repair from local tissue is possible. There is a meticulous removal of all dead tissue, careful minimal skin excision with production of a nonbevelled edge; and the best cosmetic closure done that is possible without prejudice to any late repair that may be necessary. Minor degrees of skin loss are made up by undermining, which may be of the order of 1 to 5 cm. Major flaps have seldom been used in primary repairs. Over some traumatic antrostomies with gross loss of skin, a bed of subcutaneous tissue has been fashioned, and then covered by thin split-skin graft. Primary free grafts to the face nearly always need a later cosmetic repair. Mucocutaneous suture has only been done when the tissue loss has been too great to permit primary reconstruction; the same meticulous surgery of bone and soft tissue which are closed must be done as in a primary skin closure. Whenever possible fistulae are closed at the initial operation, using mucosal flaps if necessary.

Parenteral penicillin has been used early in a number of cases. It cannot control infection in a fracture site which involves teeth and communicates with the mouth, and no decrease in bony infective complications has been noted in such cases. But in cases of early closure of facial wounds including those involving bone local penicillin reduces the incidence of suture line infection; systemic penicillin produces even quieter healing. But the general scope of early closure of facial wounds is not materially increased by penicillin.

Hemorrhage in an M. F. wound is almost always controllable by local attack on the bleeding point through the wound. We have never found it necessary to do a primary proximal arterial ligation and only very exceptionally have had to enlarge a wound to obtain access to the bleeder.

2. *Wounds of the Pharynx.*—There is a considerable difference in prognosis and in treatment between wounds of the naso- and oropharynx and those of the laryngeal part.

The upper pharyngeal wounds of this series were caused by missiles passing through antrum or ascending ramus. A thorough track toilet by finger or forceps is sufficient; repairs by either external or internal approaches are neither practicable nor necessary. Uneventful healing is the rule, except when the cervical vertebrae are involved and are comminuted. In this series of 50 pharyngeal wounds there were four cases of osteomyelitis of the spine which caused an internal pharyngeal fistula to persist.

The risks of serious infection from wounds of the lower pharynx are much greater, and probably derived from the seepage of saliva and of discharge from the fracture site into them. In wounds of the laryngeal pharynx, if there is evidence of early infection, it is often wise to convert an internal wound into an external pharyngotomy by a deliberate exposure to establish dependent drainage. But in a number of favorable early cases a full exposure of the pharyngeal hole, with excision of the track and com-

A

B



C

FIG. 2.—Primary repair of major combined mandibular and maxillary wound.

A. Mine wound of face eight hours old, with combined fractures of mandible and maxilla and an external traumatic antrostomy. The mandible was diffusely comminuted for 1 cm. in 345 region, and the roots of these teeth were fragmented.

B. A minimal but meticulous excision of all layers of the wound has been done. Comminuted displaced antral and mandibular fragments have been removed. A water-tight closure of the mouth has been effected by mucosal flaps. Involved teeth have been extracted, and the jaw fragments fixed with eyelet and direct wires, after impressions had been taken for future cast metal splints.

A thorough soap and water toilet of the face has removed most of the ingrained mud. A skin closure with fine interrupted suture-silk completed the operation.

C. The patient ten days later:

There was primary union of the whole wound by the third day, when the remaining sutures were removed. Wire fixation was changed for cast metal splints at the end of the second week.

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plete closure in layers, has been successful. A tracheotomy has been done at the same operation as primary pharyngeal closure.

3. *The Comminuted Mandible*.—Our policy has been to remove, early, all detached or infected bone, but to conserve all bone that may survive, except when a bone-gap is already present; a complete bone clearance is then done and leads to healing in a few days. Incomplete fractures are mostly best treated by a radical clearance, and closure.

Prophylactic dependent drainage of nonsuppurating mandibular fractures has not been our practice, as it delays healing time and can infect the bone.

4. *Wounds of the Antrum*.—Wounds of the antrum provide a favorable field for radical surgery and early closure. Soft tissues of the wound and track are treated by meticulous and thorough excision. Healthy intact antral and nasal mucosa is left. A good nasal antrostomy is established when the missile has not already done this. Comminuted antral wall and all maxillary fragments having no structural value are cleared out; but major alveolar fragments and orbital floor are treated with great conservatism. This radical policy with comminuted antral fragments is adopted because when these fragments are left, progressive sequestration and long-standing antral infection is the rule.

Soft tissues are closed in layers over the traumatic antrostomy. Considerable undermining may be necessary for a closure without pulling on lids or lips. Only one antrum out of a series of 40 antral closures became infected—a man who had pus in his antrum at the time of injury; the closure healed by first intention. Buccal or antral fistulae are closed whenever feasible; for these fistulae a one-layer closure by a large single flap of buccal mucosa has often been used successfully.

Hemorrhage in antral wounds is seldom troublesome at operation, and is nearly always controllable by hot packs. In one case the internal maxillary artery had to be secured through a hole in the posterior wall of the antrum.

5. *Fixation*.—A missile fracture of the jaw is best fixed within two days of injury except when: 1. There is an associated wound of tongue and pharynx with so much swelling that suffocation is likely to occur if jaws are fixed together; and 2, when nasal obstruction is present—usually fractures of maxillary block with some associated head injury—and there is a similar danger of suffocation. Intermaxillary fixation (I. M. F.) is best delayed in these cases for about a week, and whenever possible should then be done without an anesthetic.

TABLE I

SHOWING DENTAL FIXATION INSTITUTED AT THE UNIT

Cases treated by cast metal splints.....	397
Cast metal splints fitted.....	847
Cases treated by dental wiring (eyelets, direct, all types).....	500
Cases treated by per alveolar and circumferential wire.....	45
Cases treated by interosseous wiring.....	15
Cases treated by Rodger Anderson extra-oral pins.....	15
Cases treated by P.O.P. headcap C.M.S. and external rods.....	38

Wire Fixation.—A large majority of all jaw fractures can be satisfactorily treated throughout by wire; and in the first instance wiring is best for nearly all missile injuries. It is a quick method in expert hands, and can keep up with a high intake of casualties. Eyelet wiring, which we consider quicker to apply than continuous wiring, has been the most widely used method. It requires close supervision and the maintenance of 60 cases treated by wire will fully occupy one dental specialist.

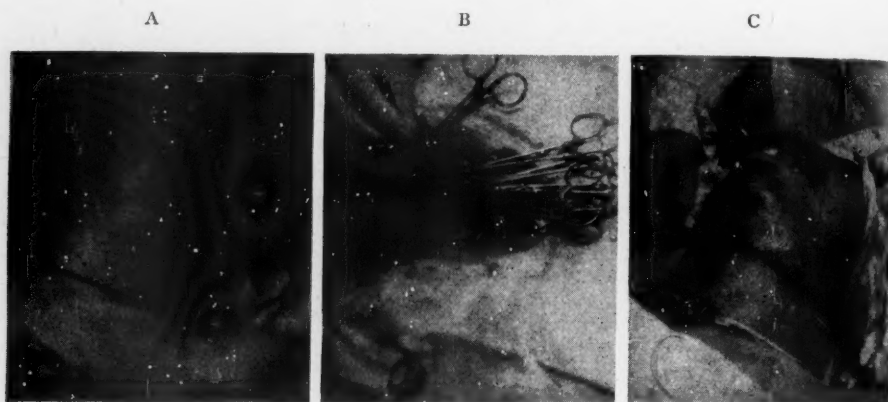


FIG. 3.—Primary repair of pharynx wound:

A. Eight-hours-old T. and T. wound comminuting lower border of right side of symphysis and passing down through left pyriform fossa and left side of laryngopharynx to emerge in front of middle of sternomastoid.

B. T. and T. wounds connected, whole tract excised and bone fragments cleared out. The dissecting forceps are being held in the pharyngeal rent.

C. Closure in layers, with drain down to pharyngeal wall. Healing was complete in ten days at which time he was eating a normal diet.

We have used wire intermaxillary fixation (I. M. F.) in preference to elastics as we believe that wire I. M. F. is firmer and better, but we have seen many cases successfully treated by elastic I. M. F. at American hospitals, and there is no doubt that both methods give good results. Elastics have been reserved by us for cases needing gradual reduction, and have been found of value.

The caliber of wire most satisfactory for general use has been 0.5 mm. stainless steel wire for the eyelets and double thickness 0.35 mm. stainless steel wire for I. M. F. Three pairs of eyelets are usually enough; but in multiple fractures up to six pairs have been used.

Some cases of scanty dentition, unusual occlusion, and some multiple fractures cannot be fixed by wire. For this minority early splints are necessary.

6. *Air-way.*—It is sound practice in military surgery to do a tracheotomy on any M. F. casualty with distress from upper respiratory obstruction which is not relieved by a simple mechanical toilet of the mouth, nose and pharynx, especially under busy conditions or when evacuation is unavoidable.

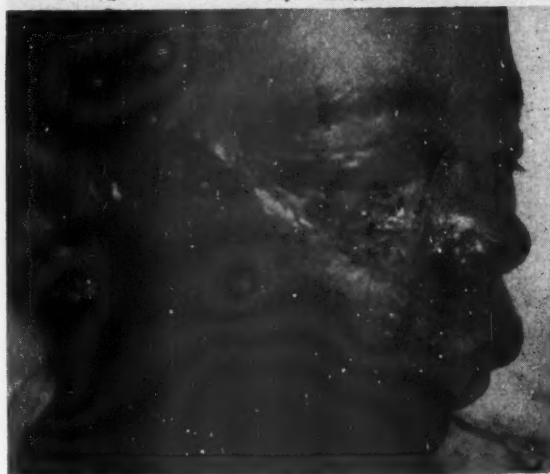
It should be done when I. M. F. is necessary in the presence of gross intra-oral damage or nasal obstruction; in most cases of primary closure of

JAW AND FACE CASUALTIES

wounds of larynx and pharynx; in emergency, for any acute upper respiratory obstruction if an endotracheal tube cannot be passed.

In all these cases a transthyroid tracheotomy is probably best, as the tube

A



B

FIG. 4.—Primary repair of antral wound:

A. Disruptive 40-hours-old wound causing destruction of orbital contents floor, lower lid and surrounding cheek, with gross traumatic external antrostomy.

B. The same four days after radical débridement of antral wall fragments and closure of antrostomy by up-turned subcutaneous flap covered with a thin split-skin graft.

is generally required for several days. Laryngotomy is reserved for cases of the most extreme urgency. Only one laryngotomy was done in this series.

It is probably true to say that too few rather than too many tracheotomies are done in Forward areas. Twenty-seven of these 1,000 cases had a tracheotomy. In one there was a serious complication (erosion of the

innominate by a low tracheotomy tube). In none of the others were there any adverse effects attributable to the tube, though it was often retained for one to three weeks during repeated evacuations.

7. *The Teeth*.—For the shell wounds of the jaw an early conservative policy with teeth is wise. Loose teeth and those easy to remove are extracted but many teeth involved in the fracture lines will survive, be of value for fixation, and cause no trouble. An attempt at early extraction of a firm tooth on a major loose fragment is very traumatic and commonly brings

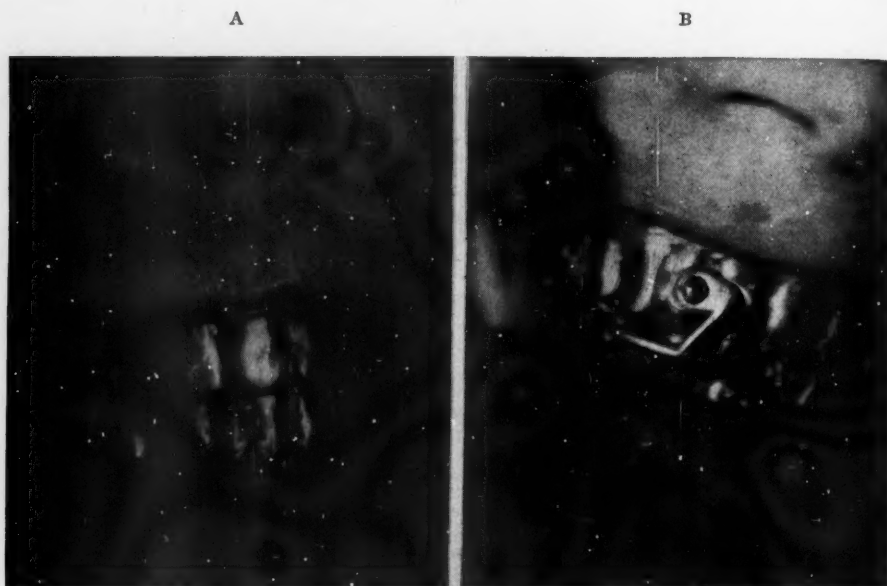


FIG. 5.—Cast metal splint fixation:

Closed cast silver splints cemented on were the standard definitive fixation used by the Unit for missile wounds of the jaws.

A. Shows intermaxillary fixation by wiring the splints together with S.S. wire.

B. Shows intermaxillary fixation and fixation across the fracture site by a locking-bar.

the bone fragment away with the tooth. On the other hand, teeth in the single fracture line of an accidental injury are best removed at primary operation, with the exception of a firmly embedded 8.

8. *Ward Care*.—For battle periods a well-lighted recovery ward, with an experienced staff, is essential.

Feeding in the early stages depends upon a well-organized ward service. The worst wounds depend upon intravenous feeding for the first two or three days. Up to 4 per cent need feeding by an indwelling Ryles tube during the first two weeks. Only four out of 1,000 cases had gastrostomies; in only one was it absolutely necessary.

As early as possible the patient is taught the importance of maintaining a very high standard of oral hygiene by his own efforts with tooth brush, pumice and bicarbonate; special irrigation machines are never used.

JAW AND FACE CASUALTIES

IMMEDIATE TREATMENT

This is the treatment of infective complications of bone and teeth, and the provision of definitive fixation.

1. *Definitive Fixation.*—Splints: Sectional cast silver closed-cap splints fitting closely round the gum margin have been the standard splints of this Unit. Open-cap acrylic splints have been used only in a small minority of cases. The fixation of closed cemented silver splints is firmer, particularly for the British soldier whose dentition is often incomplete and irregular. The objection that closed cemented silver splints cause gagging receives no support from our experience of over 800 splints fitted.

Time of application of cast metal splints (C. M. S.): We have seen the results of a large number of cases treated by C. M. S. as a routine primary method of fixation at Forward Hospital or C. C. S. level. The chief disadvantage of Forward splinting is that teeth are often included in the splint, which have to be extracted later—and extraction of a tooth incorporated in a splint may be technically difficult and harmful. Furthermore, the planning and application of a splint is best left until the course of the fracture after the primary surgery is apparent, and the case can be observed and held. There remains the minority of cases that cannot be properly fixed in any other way and in them the inherent disadvantages of Forward splinting must be accepted.

It is important to realize that to immobilize a jaw by wire all that is needed is a yard or so of wire and a pair of Spencer Wells forceps, whereas the use of splints requires a ton of heavy equipment and accommodation for a skilled dental mechanic whose maximum output at pressure is only two sets of splints a day.

2. *Other Methods of Fixation.*—About 90 acrylic, or vulcanite Gunning splints, have been fixed by per alveolar and circumferential wiring in 45 edentulous cases. This probably is a higher proportion of edentulous fractures than would be found in a similar group of U. S. Army personnel. The method gives firm fixation for four to six weeks, which is quite long enough for union in most edentulous fractures. In one case an upper Gunning splint fixed by per alveolar wires was left in and was firm for six months.

Extra-oral Roger Anderson pins have been used by us in only 15 cases, but in these they played a valuable rôle in controlling edentulous posterior fragments involving teeth or compound into the mouth. Sequestration around the pins occurred in one of our own cases, and infection around pins has been seen in seven other cases whose pins were inserted elsewhere. This is the risk of the method. Pins are unsuitable for the early treatment of shell wounds with major bone gaps as they seldom remain firm for more than six to ten weeks, deformity recurs on their removal and nothing has been gained.

Interosseous wiring has been used in 15 cases, and has been uniformly satisfactory in fixing and producing rapid union of edentulous posterior fragments in linear closed fractures.

3. *Sequestrectomy and Drainage.*—The commonest cause of infective episodes, or of a persistent sinus, is sequestration of bone fragments. Jaw wounds which are not healed in two to four weeks should be gently explored by the finger through the wound or a small suitably placed submandibular incision. Sequestra are removed and a drain inserted, and healing is expected in one to two weeks. These operations may yield one to three major sequestra (1 cm. in diameter, or more), or only a number of "seedling" sequestra. Up to the arbitrary time of eight weeks a most conservative policy is followed. Only bone which is certainly dead is removed, and no attempt at full exposure of the fracture site is made.

If the wound is not soft and dry at eight weeks a radical exploration is made through an enlarged or planned incision. All comminuted bone is removed and a drain is left in. At this late operation any bone fragment that is not certainly viable is cleared out, and the bone ends of the major fragments are freshened.

It is axiomatic that healing follows within two weeks or the operation has been inadequate, and must be repeated to avoid the interminable sinuses which occur when the care of these patients is not geared to a time-table.

4. *Soft Tissues.*—There is a useful place at this stage for secondary closure of jaw wounds which were not primarily closed, especially buccal and parotid fistulae. These operations obviate dressings and by stopping drooling from the fistula give the patient great relief.

5. *Secondary Hemorrhage.*—There were 20 cases of secondary hemorrhage. Most of these hemorrhages were minor and readily controlled in bed by simple measures. In six (1 per cent of missile wounds) bleeding occurred from an arterial gusher. These were all controlled by ligation of the external carotid on the same side. None died. The special danger of intrabuccal hemorrhage in cases with I. M. F. is rare, but every M. F. ward should have a wire-cutter and torch easily available.

6. *Teeth.*—Extractions at this stage are indicated when an involved tooth is considered to be the cause of an infective episode or the cause of a persistent sinus internal, or external. This extraction may be difficult or harmful if primary fixation has been by splints rather than by wire. Fifteen per cent of the fractures involving teeth in this series of 1,000 jaw fractures had late extractions.

LATE TREATMENT

The scope of late repairs of the M. F. casualties in a Theater of Operations is dictated by military conditions of which the number of hospital ships and number of hospital beds are the chief. In this Theater facial wounds needing tube-pedicle repair have seldom been done, and only a minority of cases with bone gaps (14 out of 52) have been grafted abroad.

Of these 1,000 cases 600 were returned to duty in the Mediterranean. This high proportion has been possible because of the large number of

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facial wounds which could be repaired from local tissue, and the small proportion of jaw wounds with bone gaps (15 per cent of missile wounds).

1. *Cancellous Chip Bone Grafts.*—Cancellous chip bone grafts have been used in 14 cases. No graft was inserted earlier than 60 days from date of wounding, and all except three cases were grafted within 100 days from being wounded. In eight cases a graft was inserted one to four weeks after soft-tissue healing. Union times varied from 32 days for 1 cm. gaps to 90 days for gaps of 6–7 cm. There were no complications in this series. All achieved union while under our care, and there has been no trouble of any sort from the iliac donor sites.

TABLE II
CHIP BONE GRAFTS FOR MANDIBULAR FRACTURES

Total Cases..... 14	
Gap	Union Time (Days)
1 cm.....	32 (7 cases)
2-4 cm.....	45 (4 cases)
6-7 cm.....	90 (3 cases)

The experience of this Unit with cancellous chip grafts is consistent with that of Plastic Centers in England in showing that this method of grafting is simple, safe and certain. It produces union more rapidly and can be used earlier than can formed cortical bone grafts. This effective method justifies bone grafting of nearly all fractures of bone gaps a month after healing. Its safety is such that we have adopted a policy of bone grafting any case which is not clinically progressing to bony union by 90 days.

2. *Scar Corrections.*—These have been done one to four weeks after final healing. This is much earlier than in civilian practice but we believe it to be the right policy under military conditions. These facial repairs are done by standard methods—by excision, undermining, and a two-layer closure after excision of dogears, or by swinging and rotation flaps or “Z” plastics.

For defects unsuitable for repair by local tissue free grafts have been used; postauricular full-thickness grafts for lower lids and thick dermatome sheets from the abdomen for cheeks and foreheads.

3. *Epithelial Inlay.*—Epithelial inlays are needed at this stage in about 5 per cent of the cases returned to duty within six months of being wounded. The reopened buccal sulcus is a uniformly receptive surface for split-skin born on a detachable G. P. mold fixed to a silver-cap splint. All cases have shown a 90–100 per cent take of the grafts, and dentures have been fitted three to four weeks after operation. Perhaps half the long-term cases need it before their repair is complete and they can wear a denture.

4. *Trismus.*—Trismus is a common sequela of missile wounds involving the muscles attached to the ascending ramus, whether a fracture is present or not. It commonly comes on after the second week.

Prophylaxis consists of chewing gum and the use of a wedge. This is enough for most cases of trismus following I. M. F.

Cases of persistent trismus due to soft-tissue injuries or fractures of the coronoid alone, are forcibly dilated under anesthesia and a prop inserted which is worn continuously for five days and then intermittently for a further ten; this has been uniformly successful and no late recurrences have been seen.

5. *Assessment of Union.*—Union in mandibular fractures is a clinical term judged by the usual clinical standards; namely, that the fracture site is firm to testing, is not tender to direct or indirect pressure, or on chewing. Reliable roentgenographic evidence of bony union is very seldom present before three months, may be much later, and is no help in deciding release of fixation. Union actually occurred somewhat earlier than the times quoted. Testing necessitates release of the fixation, takes time, and so is seldom done oftener than once a fortnight after the expected date of union.

RESULTS

In this series of complete fractures of the horizontal ramus involving teeth, caused by missiles, 110 cases united while under our care. Most of them were severely comminuted and it is remarkable that severe comminution only delayed union by about a fortnight, even though the comminuted cases often required late sequestrectomies. The analysis also shows that early surgery and fixation of the fracture lead to union one to three weeks sooner and reduce the incidence of late bone infection. The value of early treatment is best seen in comminuted fractures (Table III).

TABLE III

Shell Wounds Causing Complete Fracture of Horizontal Ramus Involving Teeth

Accidental (closed) Injuries Causing Complete Fracture of Horizontal Ramus Involving Teeth

Total cases treated, 281

Total followed through to union, 110

Total cases treated, 170

Total followed through to union, 148

SHOWING RELATION OF UNION TIME TO DEGREE OF COMMUNITION, DAY OF INITIAL FIXATION AND NUMBER OF CASES REQUIRING LATE SEQUESTRECTOMIES

	Degree of Comminution						Degree of Comminution				
	0	1	2	3	Gap		0	1	2	3	
Number of cases.....	6	15	40	40	10		108	30	10	3	
<i>Fixed within two days</i>											
Union time (days).....	41	56	58	57	0		46	48	57	0	
	(3 cases)	(8 cases)	(21 cases)	(26 cases)			(64 cases)	(21 cases)	(7 cases)		
Cases requiring late sequestrectomies.....	0	0	7	14	8		4	3	2	0	
			(8 ops.)	(25 ops.)	(9 ops.)		(6 ops.)	(5 ops.)	(6 ops.)		
<i>Fixed between 2nd and 7th days</i>											
Union time (days).....	51	45	65	76	0		44	51	78	0	
	(3 cases)	(7 cases)	(19 cases)	(14 cases)			(44 cases)	(9 cases)	(3 cases)		
Cases requiring late sequestrectomies.....	0	0	9	10	0		4	0	2	0	
			(21 ops.)	(16 ops.)			(4 ops.)		(3 ops.)		
Average union times.....	46	51	62	64			45	49	64		

In these tables degrees of comminution are as follows:

0 = single fracture lines.

1 = 1-3 bone fragments between the main fragments.

2 = 1-2 cm. of diffuse fragmentation of the mandible; in missile fractures the comminution is much finer and there is more shattering.

3 = more than 2 cm. of fragmentation, including those of diffuse comminution of the whole of one, or both horizontal rami.

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One hundred and forty-eight accidental fractures of the horizontal ramus involving teeth (Table III) were analyzed in the same way for comparison. The classification of degrees of comminution is not strictly the same as missile injuries, are usually much more finely comminuted and the fragments more scattered. In the accidental group as a whole, comminution is less and the wound and associated soft-tissue damage are much less. It is remarkable that the union times of the accidental group are practically the same as the shell group for comparable degrees of comminution; the damage to the soft tissue has apparently no effect on the process of bony union.

The aim of the primary operation is to remove all bone fragments that are infected or nonviable and to preserve all that will survive. If the surgeon is too radical he will create gaps requiring bone grafts unnecessarily. If he is too conservative there will be a high incidence of late sequestrectomies.

A comparative table was prepared to see if there were any grounds for our belief that the early surgery ought to be done by a Forward specialist team. It provided striking evidence. When the early surgery was not done by a specialist team, employing the principles described above, the incidence of bone gaps was exactly the same but late bone infection was nearly three times as common (Table IV).

TABLE IV

SHOWING THE INFLUENCE OF SPECIALISED TREATMENT ON UNION TIME, INCIDENCE OF LATE SEQUESTRECTOMIES AND INCIDENCE OF BONE GAPS IN COMPLETE SHELL FRACTURES OF HORIZONTAL RAMI INVOLVING TEETH

	Cases Treated Throughout*	Cases that Received their Early Treatment Elsewhere†
Total numbers.....	135	146
Average union time (days).....	56 (41 cases)	70 (61 cases)
Bone gaps.....	27	25
Cases that required late sequestrectomies.....	41 (52 ops.)	92 (136 ops.)

* Cases treated throughout by this Unit; early treatment of bone and soft tissues being as described, in the early paragraphs of this paper.

† Treatment undertaken from the second week.

There were only 22 fractures of the edentulous horizontal ramus in this series; and on this small group one can only say that complications were few and in their absence union took place within three weeks.

One hundred and ninety angle fractures are analyzed separately because of the peculiar problem of controlling the posterior fragment. Unreduced displacement of the posterior fragment considerably delays union and an involved eight is often left, if firm, to control the fragment and avoid displacing it by the trauma of extraction. In missile injuries there is often diffuse shattering of the angle so this policy refers particularly to the accidental group. It does not often lead to suppuration and drainage of the jaw but Table V clearly shows that union takes 10 to 20 days longer when the fracture line involves teeth. All the ten cases that required drainage involved teeth. In four cases primary extraction had been done, and in six the tooth was extracted at the first inflammatory episode. In this group, again, the soft-

tissue injury appeared to have no effect on union time and the accidental and shell fractures with comparable degrees of comminution united at the same rate.

Our standard practice with 128 condylar fractures has been to fix them in proper occlusion for three weeks, and then encourage full function and discharge them a week later. The standard incapacity time is thus a month,

TABLE V

Shell Wounds Causing Complete Fracture of Angle of Mandible

Total cases treated, 95

Total followed through to union, 43

SHOWING RELATIONSHIP OF UNION TIMES TO INVOLVEMENT OF TEETH,
TO DEGREE OF COMMUNITION, DAY OF FIXATION AND NUMBER OF
CASES REQUIRING SEQUESTRECTOMY

Accidental Complete Fractures of Angle of Mandible

Total cases treated, 95

Total followed through to union, 86

SHOWING THE RELATIONSHIP OF
UNION TIME TO DEGREE OF COMMUNITION, DAY OF FIXATION, INVOLVEMENT OF TEETH AND INCIDENCE OF DRAINAGE

	Degree of Comminution				Gap	Degree of Comminution			
	0	1	2	3		0	1	2	3
Number of cases.....	0	9	18	12	4	65	18	3	0
<i>Fixed within two days</i>									
Union time (days).....	0	48	47	55		39	50	70	0
		(6 cases)	(8 cases)	(4 cases)		(33 cases)	(5 cases)	(1 case)	
								105	
								(B.G. 77)	
Cases requiring sequestrectomy.	0	0	2	2		4	1	0	0
						(7 ops.)	(2 ops.)		
<i>Fixed between 2nd and 7th day</i>									
Union time (days).....	0	41	52	59		50	54	150	0
		(3 cases)	(10 cases)	(8 cases)		(32 cases)	(13 cases)	(1 case)	
Cases requiring sequestrectomy.	0	0	4	5		3	3	0	0
				(8 ops.)		(6 ops.)	(5 ops.)		
Cases involving teeth.....	0	50	51	58		49	55	110	0
		(5 cases)	(14 cases)	(12 cases)		(53 cases)	(14 cases)	(3 cases)	
Cases not involving teeth.....	0	40	45	0		32	35	0	0
		(4 cases)	(4 cases)			(12 cases)	(4 cases)		

TABLE VI

*Fractures of Condyle of Mandible**Fractures of the Coronoid Process*

	Fractures of Condyle of Mandible		Fractures of the Coronoid Process	
	Caused by Shell	Accidental	Caused by Shell	Accidental
Total number of cases.....	48	80	22	3
Associated with other fractures of mandible..	20	42	10 (9 A.R.)	2
Fractures of condyle alone.....	28	38	12	1
Treatment seen to completion.....	15	36	15	3
Days under treatment.....	?	Av. 29	Av. 52	Av. 32
Evacuated (all for other injuries).....	13	2	7	0
Fixation.....	Av. 28 days (20 cases)	Av. 20 days (25 cases)	10 cases	0
Major trismus.....	3	0	11	0
Duration of fixation.....	40, 42, 70 days			
Condylectomies.....	3	0	0	0
Sequestrectomies required.....	2 cases (5 ops.)	0	2 cases	0
Associated lesion of ear, eye, antrum.....	10	0	10	0
Early major hemorrhage.....	3	0	2	0
Gagging, requiring molar extraction.....	0	2	0	0

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and there were no cases of trismus, and only two that required late molar extraction for gagging (Table VI).

Missile fractures of the condyle are a different class of injury with the risk of damage to the internal maxillary artery where it is relatively inaccessible and of inflammatory complications leading to severe trismus. Hemorrhage is usually controllable by pack and pressure dressing but one case developed a false aneurysm medial to the ascending ramus which healed after external carotid ligation on the same side.

Fractures of the coronoid process (25) were not treated by intermaxillary fixation except when necessary for other associated fractures. They were characterized by a high incidence of trismus and involvement of eye, ear and antrum.

There were 89 incomplete fractures of the mandible involving either the alveolus or lower border. They can usually be treated by complete clearance of bone fragments and closure of the mucosa or skin as the case may be. Dental fixation is not necessary and they are soon fit for duty.

FRACTURES OF THE MAXILLA

Maxillary fractures were present in one-third of the missile wounds in this series (220). They range from the small puncture wound of antrum to hideous disfigurements, with much tissue loss (Table VII).

TABLE VII

<i>Fractures of Maxilla Caused by Shell</i>					<i>Accidental Fractures of Maxilla</i>				
SHOWING TYPE OF FRACTURE					SHOWING TYPE OF FRACTURE				
	Total No. of Cases	State of Maxillary		Block	Total No. of Cases	State of Maxillary		Block	
		Mobile	Floating	Firm		Mobile	Floating	Firm	
No. of cases.....	211	19	19	173	49	8	26	15	
With associated fractures of mandible.....	73		24	49	20	3	12	5	
<i>Fractures of Maxillary Block seen to union</i>					<i>Accidental Fractures of Maxillary Block seen to union</i>				
Number seen through to union, 18					Number seen through to union, 24				
Table showing influence of day of fixation on union time					Table showing influence of day of fixation on union time				
		Mobile		Floating		Mobile		Floating	
Number of cases.....		7		11		6		18	
<i>Union Time (days after injury)</i>									
Fixed within 14 days.....	27 (3 cases)			36 (8 cases)	31 (5 cases)			28 (2 cases)	
Fixed after 14 days.....	59 (4 cases)			53 (3 cases)	21 (1 case)			46 (16 cases)	
<i>Complications:</i>					<i>Complications^a</i>				
Antral infection.....			15%		Antral infection.....		8%		
Cases needing Caldwell-Luc.....			2%		Cases needing Caldwell- Luc.....		4%		
Major hemorrhage (early and late).....			10%		Tracheotomies.....		1 case		
Tracheotomies.....			5%		Death.....		2 cases		
Death.....		5-10%		2-3 due to associated cranial damage			(avoidable)		
<i>Associated injury of:</i>					<i>Associated injuries:</i>				
Eye.....			25%		Skull.....		20%		
Ear.....			5%		Eye.....		40%		
Brain.....			5%		Major limb fr.....		16%		

In 20 per cent the tooth-bearing segments are displaced and either "mobile" requiring a period of dental fixation in occlusion, or "floating" implying a maxillary block which is so loose that interdental fixation is not enough to control it; the maxilla must, in addition, be supported by fixation to the skull.

Apart from this, maxillary wounds are chiefly important because of complicating injuries. The most common of these is a fracture of the mandible which was present in 40 per cent of all cases. Eye damage—commotion, detached retina or direct injury—was present in 25 per cent of fractures of the maxillary block; 10 per cent had major hemorrhages; and fracture of the anterior cranial fossa with associated brain damage was a critical factor in nearly all the most serious cases and caused two-thirds of the deaths (5 or 10 per cent of all maxillary fractures).

The treatment of the antral wound has been described—wound excision, bone clearance, nasal antrostomy and closure whenever possible.

The treatment of cases with gross damage is to accelerate healing with the least possible deformity and without prejudicing later reconstructions. It is often possible to assist healing by carefully suturing the skin tags of a disruptive wound, and in some cases by mucocutaneous suture.

The displaced upper jaw presents many special problems. Even the most freely mobile are almost always firm to testing after 30 days fixation, but this is misleading; a mandible that is clinically firm soon goes on to bony union, but the maxilla may long remain in a condition of tough fibrous union which yields over a period of weeks if fixation is released and may redisplace or become mobile again.

It is, therefore, always necessary to reduce the maxilla into proper occlusion on the mandible at the earliest opportunity and keep it in position by I. M. F. until it is united. Even so, malocclusion recurs later in a proportion of cases but can then usually be successfully reduced by C. M. S. and powerful elastic traction or continuous traction in bed by weight and pulley.

In a floating maxilla the nasal air-way is often blocked and if early I. M. F. were done under military conditions a high proportion would require tracheotomy or they would die of suffocation. Table VII, and our experience, show that there is little disadvantage in maxillary fractures in delaying I. M. F. until the nose unblocks in five to ten days, so it has been our practice to do so, rather than do a prophylactic tracheotomy in most of the cases.

The standard method of fixation for the floating maxillary block is to apply a C. M. S. with one to three rods projecting from it through the mouth and join these to a well-fitting P. O. P. headband incorporating a metal bracket, by universal joints and one to three stout vertical connecting rods. The whole system must be sturdy and rigid.

When the upper jaw is edentulous or fractured in several places, and when there is an associated fracture of the lower jaw, the method must be modified accordingly.

Slight antral infection occurred in 15 per cent of the missile injuries but settled within six weeks on simple local treatment. Only 2 per cent of 220 wounds needed a Caldwell-Luc operation, and this was not done before the sixth week.

DEATHS

The experience of World War I was that the chief causes of death in M. F. casualties were hemorrhage and suffocation in the early stages, and chest complication and secondary hemorrhage later. These are the causes of death in this series, too, but we believe that there are fewer deaths and that secondary hemorrhage is rare and seldom fatal. In the M. F. casualty the risks of treatment can, in inexperienced hands, be much greater than the risks of the injury. This holds especially for the anesthetic risks. A major factor in the reduced mortality has been the provision of an M. F. anesthetist experienced in the intubation difficulties and the postanesthetic care of the primary operation upon these cases. The decrease in secondary arterial hemorrhages to 1 per cent is attributed to thorough early surgery of bone fragments and soft tissues and to a well-organized ward care for these jaw casualties.

The uncomplicated M. F. casualty is not often in urgent need of plasma or blood. In the Cassino battle, in which 220 M. F. casualties were treated in 12 days, only 10 per cent were given early blood or plasma, and in only about 1 per cent of these cases was transfusion life-saving. These measures have played a small part in reducing the mortality.

The majority of the deaths from infective causes—secondary hemorrhage and pulmonary infection—had had full parenteral penicillin. We have little evidence that penicillin can further reduce the mortality in M. F. casualties which have had thorough surgery.

Of this series of 1,000 jaw fractures 33 died. In 14, death was due to an associated grave injury of brain or spinal cord; and in four others (blast abdomen, infected hemothorax, sucking wound of chest, gas gangrene of thigh), the M. F. lesion was not a major factor in the death.

There remain 15 cases in which the M. F. injury was the cause of death. This gives a gross mortality of 1–2 per cent for M. F. casualties with bone damage.* The pure mandibular open wound has a mortality of .5 per cent; the closed mandibular fracture caused no death in this series. The gross maxillary mortality was 9 per cent, due to the high incidence of associated fatal brain wounds. The mortality of combined wounds of the pharynx and jaws was 6 per cent; these were all injuries of the laryngopharynx; none of the oro- or nasopharyngeal wounds died or developed deep neck or mediastinal infection.

Half the total deaths occurred within the first week. The causes of early deaths were:

* Mortality is less than .5 per cent if all wounds involving facial soft tissues and nose are included.

3 cases of hemorrhage:

Vertebral artery.

Innominate artery.

Internal maxillary artery.

1 case of suffocation.

1 case of gas gangrene of muscles of mastication (also of brain).*

1 case of carotid thrombosis and hemiplegia.

1 case of toxemia—a massive jaw wound, who also had a subdural hematoma.†

Of the seven deaths occurring after the first week, five were due to pulmonary complications. One was a ruptured false aneurysm of the internal maxillary artery (who also had an empyema and a fractured femur), and one a case of suffocation.

Three of the pure M. F. deaths were due to avoidable accidents and occurred in dark wards or tents full of fresh battle casualties. They serve to emphasize the need for a well-lighted recovery ward for M. F. cases.

This experience indicates that in M. F. casualties, which reach C. C. S. level, the chief causes of early death remain in this war as in the last—hemorrhage and suffocation; late death is, again, most commonly caused by pulmonary complications.

SUMMARY

The treatment of maxillofacial casualties in North Africa and Italy is described, with a note on the British Army arrangements for their care.

One thousand jaw fractures are analyzed. Results and different methods of treatment are discussed.

The rôle and importance of primary soft-tissue repair are stressed.

The value of cancellous chip bone grafts in the surgery of the mandible is shown.

The mortality, early and late (gross 1-2 per cent), and the incidence of arterial secondary hemorrhage (1 per cent) in jaw wounds are given and analyzed.

Our thanks are due to the Consulting Surgeons Brigadiers Weddell, Stammers, and Edwards, A.M.S., under whose direction and by whose help this work was done.

The great majority of the anesthetics for these cases were given by Major G. K. T. Roche, R.A.M.C., to whose expert anesthesia the Unit has owed its low incidence of anesthetic complications.

The treatment of the African and Italian casualties was made possible by the work of the Theater Staff—Sister P. Clutton Qaimms (R.), Cpls. Cordery and Parker, Pvts. Farwell and Waller, R.A.M.C., who made the complete arrangement for 100 to 500 operations a month for 2.5 years.

* Confirmed by autopsy section and culture.

† Died six hours after admission, 24 hours after being wounded. Autopsy showed a purulent pericarditis and a soft enlarged spleen.

Major A. Green, A.D., Corps., and Capt. W. Grossman shared in the care of the African and Italian casualties.

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1946

REPAIR OF SOFT-TISSUE WAR WOUNDS

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APPROXIMATELY 85 to 90 per cent of uncomplicated soft-tissue war wounds can be closed successfully four to ten days after adequate débridement.^{1,2,3} This policy of early closure was generally adopted in the Mediterranean Theater of Operations in the winter of 1943-44. At first only the uncomplicated wounds were so closed, but with the aid of penicillin to control infection and a blood replacement program to correct anemia, early reparative surgery of extensive and even complicated wounds also was undertaken. The general principles underlying this program have been reported by Churchill.⁴ This paper reports the experiences in a General Hospital in the Mediterranean Theater of Operations with the reparative phase of the management of soft-tissue wounds.

The goal of reparative surgery in an Overseas Theater is to obtain a closed wound: First, so that as many men as possible may be salvaged for further duty in the Theater; and, second, so that the reconstructive phase of wound surgery done in the Zone of Interior may be undertaken at the earliest possible time. Repair of soft-tissue wounds may be undertaken (a) early (between the fourth and tenth days); (b) late (after ten days); or (c) by a planned stage method which will be described. In any case, the actual repair is accomplished by either (1) approximation of skin edges; (2) skin grafting; (3) simple plastic procedures, such as advancement of flaps; or (4) a combination of the three methods.

COMPARISON OF METHODS

Early repair is more successful than late repair because of a low incidence of infection. Technically, it is also more easily accomplished and results in better function of the injured part because of minimal scar tissue formation. The contraindications to early repair are (1) frank purulent discharge from the wound; (2) presence of devitalized tissue in the wound; (3) redness, tenderness and induration about the wound edges; or (4) abnormal elevation of temperature. Experience during the Italian Campaign has shown that these contraindications are rarely encountered if débridement has been adequate, so that repair can be undertaken without delay. If there is only minimal infection present, the wound is allowed to "clean-up" with the aid of moist and resilient pressure dressing. This may delay repair beyond the ideal four- to ten-day period. In other cases the planned stage method of repair is carried out. The first stage consists of the removal of devitalized tissue and the drainage of pus pockets. Four to six days later the second stage (repair) is carried out, the viable tissues having been protected in the intervening period by the administration of intramuscular penicillin. The correc-

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tion of anemia with transfusion of whole blood plays an important part in the success of this method.

Early repair is seldom complicated by serious infection for several possible reasons: First, the wound by the end of the fourth day has developed a strong resistance to infection; second, there is little chance for further wound contamination since the dressing applied after initial surgery is usually not changed until the time of reparative surgery; and, third, it is usually accomplished with a minimum of manipulation or trauma. Partial or total failure results, on the other hand, in a greater percentage of late repairs because of infection. There are several reasons for this. The longer a wound is open, the greater chance there is for it to become contaminated and, therefore, for it to serve as a source of infection. In late repairs dissection is necessary into fresh tissues which have not developed resistance, since the wounds have to be excised in whole or in part and the edges undercut. The difficulty of hemostasis and the unintentional closure of some of these wounds under tension are additional factors that increase the incidence of infection.

Repair between the fourth and tenth days is technically more easily accomplished than late repair because of the pliability of tissues due to the absence of excessive scar tissue at this time. This is very important in extensive wounds when, even with minimal skin loss, there is wide separation of skin edges. These can usually be approximated early by simple suture, while if repair is delayed, the tissues become so contracted and fixed by scar tissue that skin grafting or other plastic procedures have to supplement wide undercutting of the wound edges before a closed wound can be obtained.

Analysis of Cases.—During the first three months of 1944 a careful check of early and late closure was kept on 691 wounds in 422 battle casualties. Results were classified as "A" when healing to all intents and purposes was *per primam*; "B" when healing was with minimal reaction, such as serum and stitch infections, but without loss of skin approximation; or "C" when there was gross infection with partial or total separation of skin edges.

In 391 of the wounds, closure was by simple approximation less than 12 days after débridement. Healing was classed as "A" in 370, or 94.6 per cent; as "B" in 15, or 3.8 per cent; and as "C" in 6, or 1.5 per cent.

Closure was done late in 300 wounds. Sixty of them were closed by simple approximation but all were done 12 days or more after débridement. In this group healing was "A" in 37, or 61.7 per cent; "B" in eight, or 13.3 per cent; and "C" in 15, or 25 per cent. Partial or total excision before closure was done in the remaining 240. Healing was classed as "A" in 180, or 75 per cent; as "B" in 31, or 12.9 per cent; and as "C" in 29, or 12.1 per cent. The figures for the combined late group were "A" 72.3 per cent; "B" 13 per cent; and "C" 14.7 per cent.

EARLY REPARATIVE SURGERY

Preparation.—Patients with soft-tissue wounds usually reach the General Hospital in the Base by the third, fourth or fifth day after injury. Because

there are so many advantages of early repair, it has been described by Rogers⁵ as a "surgery of necessity." Operation is delayed long enough, however, for the patient's condition to be checked and to allow him to recover from the fatigue resulting from his transportation. Blood values are determined when indicated and anemia, if found, is corrected by transfusions of blood. Additional roentgenologic examinations were also made, if necessary, to determine the presence or location of metallic foreign bodies. If temperature is not abnormally elevated, the patients are taken to the operating room, preferably on the fourth or fifth day, and the wound exposed for the first time since initial surgery under aseptic conditions. Clinical judgment rather than bacteriologic studies determines whether or not the wound should be closed at this time. Experience with the management of over 3,000 casualties with soft-tissue injuries has shown that this can be done successfully even when the wound surface appears "mucky." We know that the surfaces of many of the wounds are contaminated and a bacteriologic report would only confuse the issue and unnecessarily delay repair. A majority of wounds are closed under intravenous sodium pentothal but if the operation is likely to extend much beyond 30 minutes, nitrous oxide-ether inhalation anesthesia is preferred. The skin about the wound is cleansed with ether and then painted with one of the accepted antiseptics. The usual wound in the early period has a freshly-cut appearance which "invites" repair. If blood clots are present, they are carefully removed. Small metallic foreign bodies not found at initial surgery are not searched for, unless it is felt that they can be readily located without too much disturbance of the wound or if their location near vital structures or joints may cause future trouble. They are rarely responsible for the failure of wound healing.

Repair by Approximation of Skin Edges.—In the majority of soft-tissue wounds, closure is by the simple approximation of wound edges provided there has not been excessive loss of skin. Towards the end of the period in which early closure is possible the wound edges begin to roll in. If this is the case, they are gently freed up with a blunt instrument. Approximation is by simple or vertical mattress sutures of silk or silkworm gut on large skin needles. Wound edges are sometimes so widely separated because of edema that they cannot be reapproximated with these types of sutures. A far-near-near-far type of tension suture, such as is commonly used to close the skin of the chest wall after radical mastectomy, is of value under these circumstances. Approximation is made under moderate tension in violation of this principle of surgery because as soon as the wound is closed edema subsides and the tension is lessened before strangulation of the incorporated tissues takes place. An attempt is made to encompass the wound, or at least the open portion of it, with the sutures in order to obliterate dead space. The fascia is included in the sutures but no attempt is made to do a separate layer suture. Only occasionally is a symptomatic muscle hernia seen because of failure to suture separately the fascia and these are usually small defects which are easily corrected if necessary. On the other hand, we feel that

routine layer closure would result in a higher incidence of infection because of the additional tissue dissection required and because of the presence of buried suture material. Obliteration of dead space is not difficult in the majority of wounds because of their anatomic location on the extremities. They are usually located in the long axis of the limb and the closure of the wound snugs the skin around the part and aids in obliteration. A resilient pressure dressing is of further aid. Wound drainage is only employed when

A

B

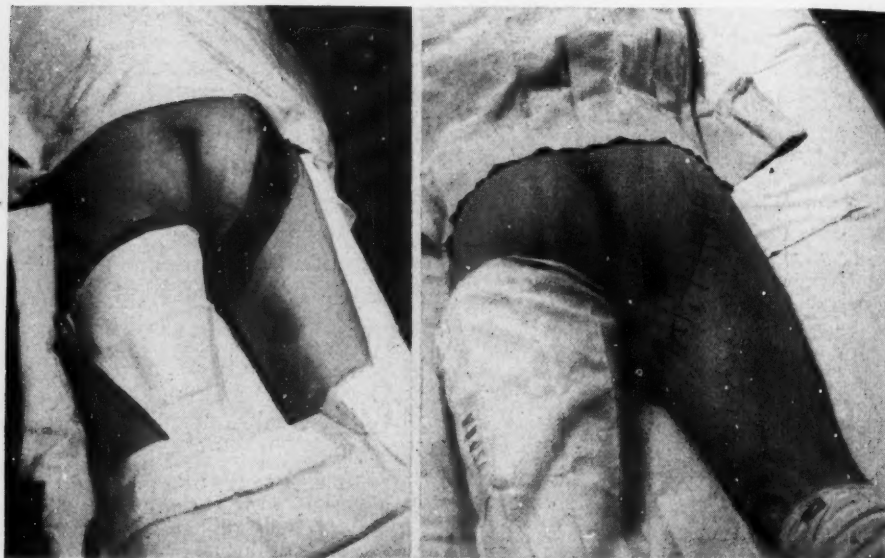


FIG. 1.—Case 1: Repair of wound by simple approximation five days after débridement of perforating wound. (A) At time of closure. (B) After removal of sutures 14 days after closure.

deep pockets cannot be obliterated; when there is profuse drainage from a long perforating wound; or when there is surface infection, as is described in Case 3. Rubber tissue is the material of choice for drainage.

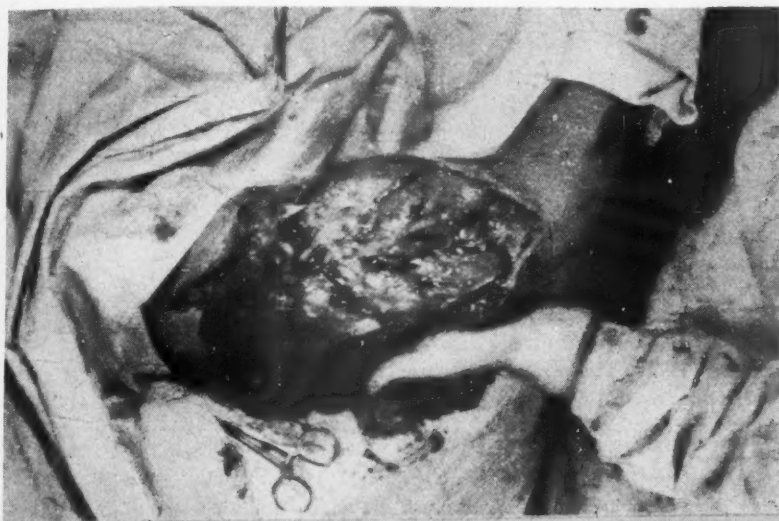
The following case illustrates repair by reapproximation:

Case 1.—(Fig. 1): An American soldier, age 19, was wounded in action in the right buttock by a high explosive shell fragment, February 29, 1944, on the beach-head at Anzio, Italy. The wound was perforating, with the wound of entrance on the lateral aspect of the buttock and the wound of exit on the mesial aspect of the upper thigh. Débridement was done at an Evacuation Hospital 16 hours after injury. A diagnosis of anaerobic cellulitis was made at this time. The tract was opened widely throughout its entire length, which necessitated almost complete division of the gluteus maximus muscle. He was evacuated by boat to a General Hospital, in Naples, where he was received March 3. He was found to be in good condition and delayed primary suture of the incised wound, which measured 33 x 7 cm., was done March 5 (five days after injury), under sodium pentothal intravenous anesthesia. The wound was clean and healthy in appearance. The wound surface was dusted with sulfanilamide powder and closed with silkworm gut sutures. It healed uneventfully except for minimal drainage

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at the mesial angle. Sutures were removed on the 10th postoperative day. The only chemotherapy was sulfadiazine by mouth for seven days after wounding. He was discharged to duty after reconditioning on May 11, 72 days after injury.

A



B

FIG. 2.—Case 2: Repair of wound with extensive skin loss by partial approximation of skin edges and skin grafting eight days after débridement. (A) At time of repair. (B) At time of first dressing 12 days after repair.

Repair by Skin Grafting.—When skin loss or edema does not permit approximation of skin edges or only allows partial approximation, the wound is covered with a split-skin graft in preference to rotation or advancement of skin flaps. We have rarely employed the latter method, but occasionally it

may be useful. Complicated plastic procedures are better undertaken after the wound has healed, edema has subsided, and the danger of lighting-up infection has passed. Skin grafting is nearly always successful on a fresh wound. The grafts are fitted to the outline of muscle groups and into pockets and crevices when necessary. A resilient pressure dressing is employed.

Case 2.—(Fig. 2): An American soldier, age 29, was wounded in action by a rifle grenade on March 18, 1944, at 2300 hours, on the beachhead at Anzio, Italy. He received multiple wounds but the most serious was an extensive avulsed type of wound of the right arm with severe compound, comminuted, fracture of the humerus. Débridement was done at an Evacuation Hospital shortly after injury. He was evacuated on March 23 to a General Hospital, in Naples, where he was found to have an extensive soft-tissue defect on the right upper arm, measuring 30 x 22 cm., with numerous exposed fragments of bone in the wound and with copious drainage of serum. Intramuscular penicillin therapy in doses of 25,000 units every three hours was started, and the anemia was corrected with transfusion of blood in preparation for reparative surgery. On March 27 (eight days after injury) under nitrous oxide-ether anesthesia, with the aid of Major R. D. Butterworth in the management of the fracture, all loose bone fragments were removed, the main fragments interlocked, and exposed bone covered with muscle. The upper and lower ends of the wound were closed with silkworm gut, but a defect 28 x 20 cm. remained. This was covered with small split-skin grafts which were fitted to individual muscles and into crevices. They were not sutured in place. A resilient pressure dressing and a plaster shoulder spica, with the arm at 80° abduction, was then applied. The wound was exposed through a window in the encasement 12 days later and found to be healing satisfactorily, with practically a 100 per cent take of the grafts. Unfortunately, the fracture of the humerus angulated slightly and a spike of bone had protruded in the center of the wound. The soldier was evacuated to the Zone of Interior on April 28 (41 days after injury) with a closed wound.

COMMENT: This wound was complicated by a compound fracture but it illustrates the repair of a wound with extensive loss of skin. Internal fixation of the fracture probably would have prevented the protrusion of the bone through the wound, but this program had not been undertaken at the time. This patient later required bone and soft-part reconstructive surgery, but it was undertaken at a much earlier date. Also, as a result of the early reparative surgery, chronic infection and debilitation from the loss of serum from a large open wound was prevented.

LATE REPARATIVE SURGERY

Closure after the tenth day is not by choice, but either because of the contraindications previously described or because evacuation to the Base is delayed by chest, abdominal or other serious wounds beyond the period in which early closure can be done. The granulating wound often becomes infected as a result of repeated contamination at the time of change of dressings and is a frequent cause of failure of wound healing. Careful preoperative preparation is, therefore, necessary. Moist saline dressings or pressure to "dry out" the granulations are sometimes necessary to prepare these wounds for surgery. In the case of large or deep wounds the skin edges only are excised and undercut and approximation made over the granulating bed. This

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eliminates much bleeding and reduces the extent of tissue spaces that are opened by dissection. In small wounds it is usually more satisfactory to excise the wounds *en bloc*. Because of fixation and scar tissue or because of loss of skin, wound repair often must be accomplished by skin grafting or other plastic procedures instead of by simple suture. As has been pointed out previously these procedures are more difficult and not as successful as when done early.

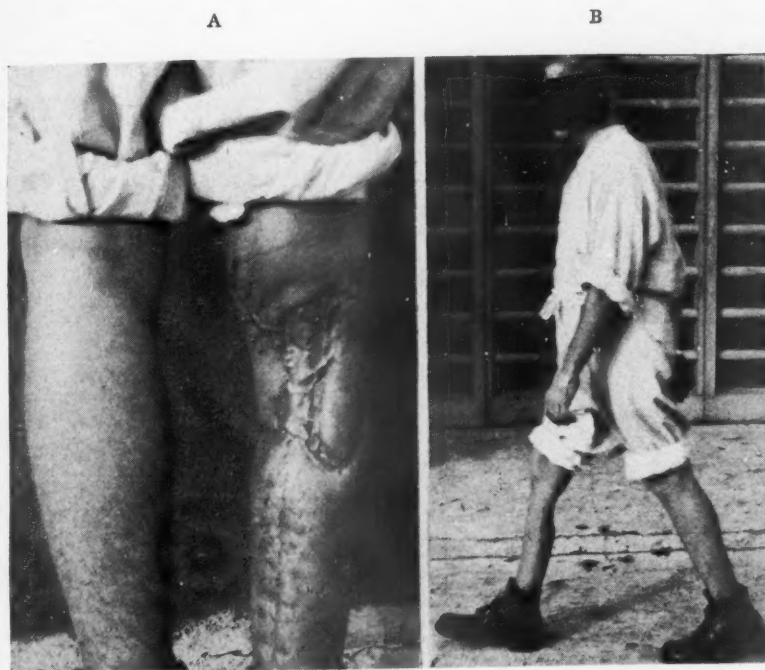


FIG. 3.—Case 3: Repair by stage method. Gastrocnemius and soleus muscles removed six days after initial débridement and repair done five days later. (A) and (B) Shows appearance and function of leg 40 days after injury.

STAGE REPARATIVE SURGERY

Some wounds when seen in the General Hospital after initial surgery are found to be infected usually because of devitalized tissue that was not recognized at the time of débridement or because of retained foreign material, usually nonmetallic. Many of these cases are handled by a planned two-stage procedure. Secondary débridement and the establishment of adequate drainage is first done, and five days later the wound closed in the same manner as described for early repair. The viable tissues in the intervening time are protected against infection by systemic penicillin and anemia is corrected with transfusions of whole blood. Two case reports will best illustrate the details of this method:

Case 3.—(Fig. 3): An American soldier, age 24, was wounded in action in the posterior aspect of the upper third of the right lower leg by a high explosive shell frag-

ment, September 29, 1944, in Southern France. The wound was lacerating in type and divided the gastrocnemius and soleus muscles near their origins. Débridement was done at an Evacuation Hospital several hours later and a circular encasement applied. He was evacuated by air, September 30, to a General Hospital, in Naples. He was comfortable and in good general condition on admission. He was, therefore, scheduled for inspection of the wound and reparative surgery, if indicated, on October 3 (six days after injury). During the intervening period the temperature had been elevated between 99° and 99.6° F., but because of the description of an extensive wound, this was not thought to be abnormal. When inspected in the operating room, the distal ends of the gastrocnemius and soleus, however, were found to be gangrenous due to ischemia. Both muscles with the tendo achillis were removed under intravenous sodium pentothal supplemented by nitrous oxide-ether inhalation anesthesia. The wound was dusted with sulfanilamide powder and a resilient pressure dressing with dry, fine-mesh gauze applied next to the wound. A posterior plaster splint completed the dressing. The patient had received penicillin intramuscularly in doses of 25,000 units every three hours since wounding, and this was continued. He was given 500 cc. transfusions of whole blood on October 3, 4 and 6, to correct anemia, and on October 8 (five days after the first stage), under intravenous sodium pentothal anesthesia the 40-cm. longitudinal wound, made for removal of the gastrocnemius and soleus muscles, was closed with silkworm sutures. The irregular defect over the original wound, which measured 15 cm. in diameter and which could not be closed, was covered with split-skin grafts. A resilient pressure dressing with a circular plaster encasement was applied. Penicillin therapy was continued for seven days. Healing took place with minimal reaction and the skin grafting was 100 per cent successful. Sutures were removed on the 12th postoperative day. Physiotherapy was started on November 7, and when evacuated to the Zone of Interior, December 23 (87 days after injury), he was walking without aid and with only a slight limp. A letter received from the soldier, dated February 21, 1945, stated that he was getting along fine.

COMMENT: Because of the gangrene of the soleus and gastrocnemius muscles, serious consideration was given to amputation of the leg. This soldier now has a useful leg, with surprising ability and power of plantar flexion.

Case 4.—(Fig. 4): An American soldier, age 28, was wounded in action in the anterior lateral aspect of the upper third of the right thigh by a high explosive shell fragment, May 25, 1944, near Cisterna, Italy. The wound was penetrating in type. Débridement of the wound and removal of the shell fragments was done shortly afterwards at an Evacuation Hospital, and the patient evacuated, on May 28, to a General Hospital, in Naples. Examination on admission revealed an acutely ill soldier with a temperature of 104° F., and a pulse of 112. Inspection of the wound, which measured 8 x 3 cm., revealed old blood mixed with gas bubbles exuding from it. The area about the wound was acutely tender and swollen. A tentative diagnosis of anaerobic cellulitis rather than *Clostridial* myositis was made.

Under ether inhalation anesthesia, the thigh was opened widely by an incision that extended from the suprapatellar region up the anterior lateral thigh to a point just below the anterior superior iliac spine, and then extending laterally and upwards for an additional ten centimeters. An incision was made in the lateral aspect of the wound edge to afford adequate exposure. Hemorrhage had dissected between the tissue planes of the muscles of the anterior and lateral thigh, and the vastus lateralis and the muscular portion of the tensor fascia lata were gangrenous. These were excised, muscle planes opened widely, and all clotted blood carefully cleaned out. The wound was filled with activated zinc peroxide paste, and a dry, fine-mesh gauze dressing applied. *B. subtilis*,

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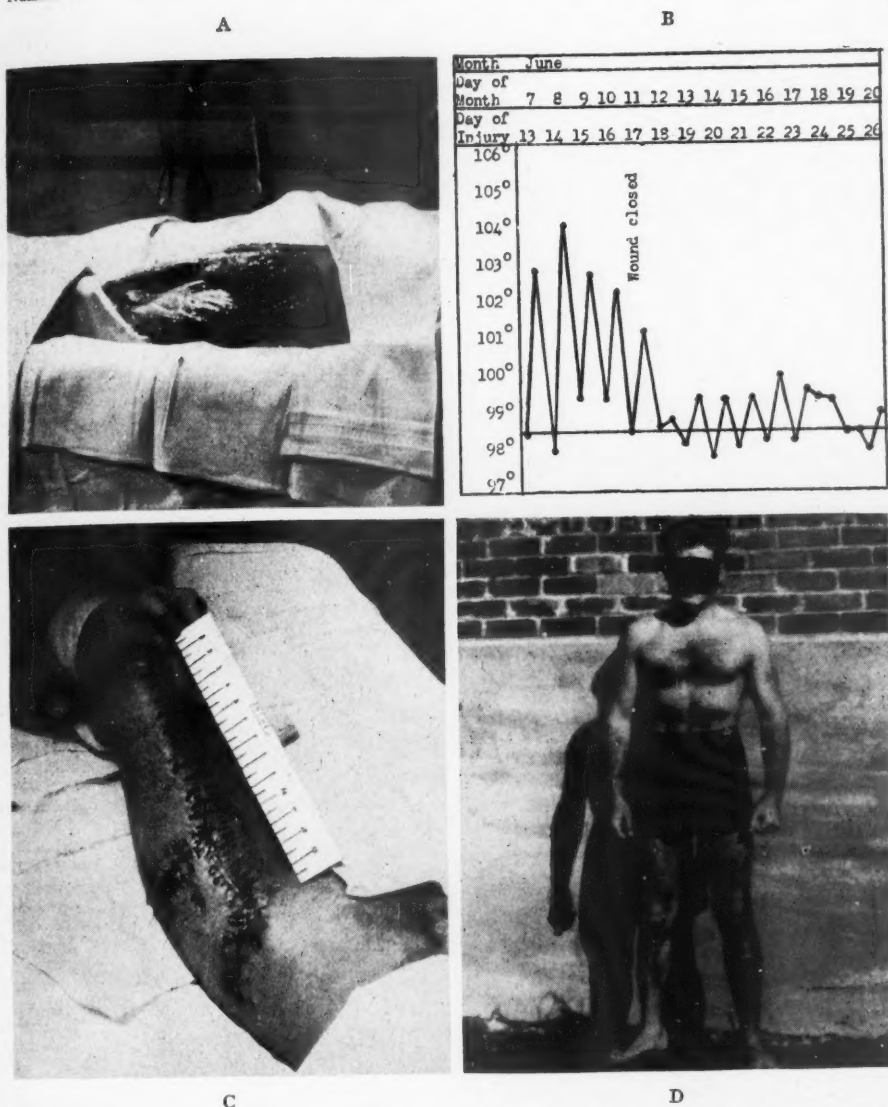


FIG. 4.—Case 4: Repair by stage method. Secondary débridement done three days after initial débridement, and repair completed 14 days later. (A) At time of repair. (B) Temperature curve immediately before and after closure of wound. (C) Appearance of wound 14 days after closure. (D) Soldier in January, 1945.

Streptococcus viridans and micrococci were cultured from the wound. Penicillin, which he had received intramuscularly in doses of 25,000 units every three hours since initial surgery, was continued. A transfusion of 500 cc. of whole blood was given in the operating room and a second on the return of the patient to the ward. There was such a profuse seropurulent discharge from the wound that the dressings had to be changed at the end of three days and thereafter at similar intervals. There was a momentary drop in temperature after surgery but later it ranged between 100° and 103° F. The second stage (repair) was, therefore, delayed. On June 8, the dressing was found soaked in blood. The source was not found since all bleeding had ceased when the wound was

examined. In view of the hemorrhage it was decided that it would be wise to go ahead with wound closure in spite of the gross contamination of the wound surface and the elevated temperature. The blood values at this time were: red blood count 2,190,000, hemoglobin 7.5 grams per cent, hematocrit 22 per cent and serum protein 5.15 mg. per cent. He was given 2,000 cc. of blood in the next three days to correct the anemia. Re-approximation was done on June 11 (14 days after secondary débridement), under nitrous oxide-ether inhalation anesthesia.

When old clotted blood was cleaned out from beneath the upper portion of the sartorius muscle preparatory to closure, there was a gush of arterial blood that carried a distance of 15 feet. This was found to be coming from a hole in the superficial femoral artery. The hole was obstructed with the nose of a Kelly clamp to control bleeding while suture ligatures of plain No. 1 catgut were placed. When tied, these satisfactorily closed the defect. The skin edges were then approximated under considerable tension with silkworm gut sutures. Small rubber tissue drains were inserted at several points. Following closure the temperature dropped to normal where it remained except for minor elevation up to 99° F. Penicillin was continued for seven days after closure. Healing took place with a minimum of reaction and sutures were removed on the 12th postoperative day. The patient was given a total of 5,000 cc. of blood. Physiotherapy was begun on July 2, and when he was evacuated to the Zone of Interior, August 21, his wounds were firmly healed but there was restriction of knee flexion to 90°. A letter received, dated January 10, 1945, states that he has excellent function of the leg.

COMMENT: Surface infection in extensive wounds may cause a marked febrile reaction but, if gross devitalized tissue has been removed, repair can be successfully undertaken with the aid of penicillin and blood replacement therapy. We have had similar experiences in several other cases. Delay in closure in this case might have resulted in fatal hemorrhage from erosion of the femoral artery. Repair at a later date, also, would have been difficult and probably would have required skin grafting or other plastic procedures.

AFTER CARE OF WOUNDS

There are a number of things in the after care of repaired wounds which deserve to be stressed. The adjacent joints are splinted to insure rest of the part and a resilient pressure dressing is applied to aid healing by preventing the stasis of fluids in tissue spaces. Sutures are left in place from 10 to 12 days, since healing is probably slower after either early or late delayed closure than after a primary closure. If the patient does not have an abnormal rise in temperature or discomfort in the wound area, the original dressing is not disturbed except for the removal of sutures, unless drains have been inserted. These are removed usually on the fourth postoperative day. When infection develops in a wound, conservatism is practiced. By the judicious removal of an occasional suture and the application of moist dressings of magnesium sulphate or boric acid solution, approximation may be maintained at least in part. Physiotherapy in the form of whirlpool baths, active and passive exercises, and heat is begun as soon as the wound is firmly healed.

VALUE OF CHEMOTHERAPEUTIC AGENTS

Penicillin is a valuable adjunct to successful reparative surgery. It is given intramuscularly in dosages of 25,000 units every three hours to nearly

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all battle casualties from the time of their initial surgery until the condition of their wounds can be evaluated in the Base. Many of the less severe soft-tissue wounds are repaired without further penicillin or sulfanamide therapy. The program of early soft-tissue repair was successfully underway before penicillin became generally available. Before then sulfadiazine was given orally to all battle casualties for seven days after injury. Penicillin is continued for several days after the repair of wounds in which there has been extensive muscle damage, particularly as a safeguard against the development of *Clostridial* myositis. It is given in all cases treated by the stage method. Some wounds have been dusted with sulfanilamide powder when there was some question as to surface contamination but as more experience has been gained its use has been almost entirely discontinued.

REHABILITATION OF THE LIGHTLY WOUNDED

The lightly wounded form a valuable potential reserve for the Army, and if the greatest possible number are to be salvaged for further duty in the Theater, rehabilitation requires careful attention. The further a soldier is evacuated from the front and the longer he is away, the more difficult it is to return him to duty. Lightly wounded casualties are not evacuated any further to the rear than is compatible with adequate treatment and the tactical situation. In the General Hospital in the Base, efforts are directed towards weaning the patient from crutches and cane and from an inside hospital bed as rapidly as his condition will warrant. He is required to wear his combat shoes instead of slippers as soon as possible, as they apparently greatly aid in his rehabilitation by giving his feet proper support. Special attention is paid to the conditioning of quadriceps muscles because of the disability that results from disuse atrophy. This is particularly a problem when the wounds involve only one extremity. Natural favoring of the part causes the patient to limp, which increases the atrophy of the muscle. The atrophy further exaggerates the limp and the more he limps the greater the atrophy becomes. This vicious circle is sometimes difficult to break. He is moved to a ward tent where he sleeps on a cot as soon as his wounds do not demand active attention. This is usually between two or three weeks after injury in the more lightly wounded. This move is deliberately made as a part of mental reconditioning that is often necessary for return to duty even though sufficient inside beds may be available. If a patient spends his entire period of convalescence in one place, he is apt not to be keenly conscious of the improvement he has made. This procedure also allows the more recently injured casualties who require active therapy to be concentrated in one place. When he is a little stronger, he is evacuated to the convalescent section of the hospital, where he hikes, drills, takes calisthenics, participates in athletic contests and performs other duties about the hospital on a graded basis depending on his physical condition. Lectures are given by convalescent officers on the present tactical situation and on subjects of military science. The patient is usually held in this section for two weeks. He is checked at least

twice a week by his original ward surgeon to determine progress and to determine when he is ready to return to duty. Every effort is made to build up a man's unit pride by asking him questions about it or by commenting on its good record. Many men can be returned straight to duty from this section but others require additional reconditioning, and are sent to a reconditioning company for a period of three weeks. They are checked by a medical officer at the end of this time and, if not ready for discharge, are either held for an additional period or are returned to the hospital for further study and disposition by his original surgeon.

SUMMARY AND CONCLUSIONS

1. The goal of reparative surgery of soft-tissue war wounds in an Overseas Theater of Operations is to obtain a closed wound: First; so that as many men as possible may be salvaged for further duty; and, second, so that the reconstructive phase of wound surgery done in the Zone of Interior may be undertaken at the earliest possible time.

2. Early repair is more successful than late repair because of a lower incidence of infection and, also, is more easily done because of the greater pliability of the tissues at the time.

3. A two-stage plan of management is often employed in some wounds that are still infected or still contain devitalized tissue. The wound is cleaned up at the first stage and, five days later, it is repaired, infection having been controlled by intramuscular penicillin in the meantime.

4. Repair in any case is accomplished by either (1) approximation of skin edges; (2) skin grafting; (3) simple plastic procedures, such as advancement of flaps; or (4) a combination of the three methods.

5. Penicillin therapy and the correction of anemia with transfusions of blood are of great value as adjuvants to the repair of extensive or complicated wounds.

6. Rehabilitation is stressed in order to salvage the largest possible number of the more lightly wounded for further duty in the Theater of Operations.

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PULMONARY EMBOLISM

A STATISTICAL STUDY: WITH PARTICULAR REFERENCE TO THE VALUE OF CERTAIN PREVENTIVE MEASURES

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IT IS UNNECESSARY to point to the importance of the subject of pulmonary embolism to justify this study and report. Although several preventive measures have become available during the past few years, the number of surgical patients who die from this cause is still too large. This review of the Henry Ford Hospital material was undertaken at the suggestion of Dr. Roy D. McClure. It is concerned with 118,611 operations performed in a 21-year period, from 1924 through 1944. Two hundred and eighty patients had pulmonary emboli, of which 78 were fatal. The complication was responsible for the death of one patient in each 1,500 operated upon for all reasons. The diagnosis was established by autopsy in 70 per cent of the fatal cases.

The yearly incidence of embolic episodes is shown in Table I. The first two-thirds of this table is inserted more to show the source of the 280 cases analyzed than to give an absolutely accurate picture of the incidence of the complications over the entire period. It is well known that a wave of interest in a subject produces an increase in the number of diagnoses. For example, the table indicates that in 1937 there were only six nonfatal infarcts, while in 1941, with no increase in the number of operations, there were 30. For locating cases previous to 1938, we were dependent on the regular hospital indexing system. Since that time, the case numbers have been obtained from the minutes of the monthly surgical staff meetings which are attended by operating surgeons, residents, interns and anesthetists. In these meetings there has been a reasonably thorough reporting and appraisal of all embolic complications. Attention is called to the fact that in the year 1930, before the days of heparin for clinical use, dicumarol, femoral vein ligation and early ambulation, there was not a single fatal pulmonary embolus, while in 1943, when all of these preventive measures were available, there were eight! However, it can be stated that none of these eight cases was given specific prophylactic treatment. The fatal episode was without warning in seven cases; in the remaining case, death occurred before the recommended vein ligation was carried out.

All cases, both fatal and nonfatal, have been tabulated with regard to sex, age, type of operation and the postoperative day of the attack. An analysis has been made of the chief symptoms of the cases who survived and two tables relating to fatal episodes are given.

Sex.—In Table II, it will be noted that both fatal and nonfatal embolism

* Now in Military Service.

occurred more frequently in men than in women, the ratio being approximately 3:2. This is in agreement with the Mayo Clinic study¹ of 172,888 operations, which showed an incidence of 0.605 per cent of total embolism for men and 0.442 per cent for women.

Age.—It is well known that the complication of pulmonary embolism affects the older age-groups most often (Table III). In this series, pulmonary infarct occurred only once in persons under 20 years of age. All embolic

TABLE I
YEARLY INCIDENCE OF EMBOLISM AND INFARCTION

Year	Operations	All Embolic Episodes	Fatal Embolisms
1924.....	5608	6	3
1925.....	5479	9	4
1926.....	5674	7	3
1927.....	4926	10	4
1928.....	5300	13	6
1929.....	5845	12	5
1930.....	5147	4	0
1931.....	4917	14	6
1932.....	4748	5	1
1933.....	3755	4	0
1934.....	5425	12	1
1935.....	6066	14	4
1936.....	6056	13	4
1937.....	6504	8	2
1938.....	6105	17	5
1939.....	5106	25	4
1940.....	5835	24	5
1941.....	6148	33	3
1942.....	6340	22	5
1943.....	6175	17	8
1944.....	7452	11	5
Totals.....	118,611	280	78

TABLE II
SEX INCIDENCE

	All Embolism	Fatal Embolism
Males.....	166	46
Females.....	114	32
	280	78

TABLE III
AGE INCIDENCE

Age-Group	All Embolism	Fatal Embolism
0-9 yrs.....	0	0
10-19.....	1	0
20-29.....	18	3
30-39.....	57	8
40-49.....	73	15
50-59.....	62	17
60-69.....	46	22
70-79.....	20	10
80-89.....	3	3
	280	78

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TABLE IV
INCIDENCE OF EMBOLISM AFTER CERTAIN OPERATIONS

Operation	Number	All Embolism	Fatal Embolism	Percentage Fatal Embolism
Hernia.....	7887	42	6	0.076
Fractures.....	5199	39	12	0.23
Hysterectomy.....	3833	35	6	0.16
Cholecystectomy.....	2883	24	6	0.21
Prostatectomy.....	756	19	8	1.06
Appendectomy.....	5450	15	4	0.075
Stomach operations.....	858	13	7	0.82
Colon operations.....	448	8	3	0.67
Breast operations.....	1461	4	3	0.20
Brain operations.....	810	2	1	0.12
Miscellaneous urology.....		13	6	
Miscellaneous trauma.....		12	1	
Amputations (lower ext.).....		10	3	
Postpartum.....		6	1	
Miscellaneous gynecology.....		6	1	
Miscellaneous orthopedics.....		6	3	
Varicose vein operations.....		6	0	
Ophthalmology.....		3	0	
Phlebitis.....		3	1	
Hemorrhoidectomy.....		2	1	
Miscellaneous.....		12	5	
		280	78	

episodes occurred most frequently in the fifth decade, while fatal embolism was noted most often in the sixties. It is evident that patients above the age of 40 must receive special attention.

Type of Operation.—Table IV presents a tabulation indicating the incidence of embolism following certain common operations. It was expected that abdominal operations would show the complication frequently, and head and neck operations not at all. This was the case. Gastric operations and prostatectomy were the worst offenders, showing an incidence of about one in a hundred for fatalities. On the other hand, the operation of thyroidectomy was not accompanied by a proven case of embolism. For cholecystectomy, the incidence is 1:500, for hysterectomy, 1:600, and for hernia and appendectomy, 1:1300.

Postoperative Day.—(Table V): It is interesting to note that there are two peaks of fatal embolism in this table, on the sixth and eleventh days. This would correspond to the time of getting patients up to go home at the end of one or two weeks, respectively. Early ambulation, as advised by Leithauser,² and others, should change this tabulation in subsequent years.

Clinical Symptoms and Signs.—(Table VI): The cardinal sign of minor embolism is pain in the chest. The patient may say that it is in his back or "kidney," but sooner or later it is evident that there is pleural irritation on one side or the other. The ratio of pain on the right side to that on the left was 5:3. Hemoptysis, physical signs and positive roentgenographic findings were each present in about half of the cases. A friction rub was noted in a third and an effusion was demonstrated roentgenographically or by thoracentesis in a fifth of the cases.

Circumstances of Fatal Episodes.—The possibility of carrying out the Trendelenburg operation of pulmonary embolectomy has been the subject of much speculation. There is no report of a successful case in this country, and such an authority as Graham³ has stated that he is doubtful if the operation is ever indicated. Nevertheless, for those who may be interested, the interval before death and the time of day of the episode in each case are tabulated. (Tables VII and VIII.) Almost half of the cases died in less than ten

TABLE V
POSTOPERATIVE DAY OF EPISODE

Day	Nonfatal	Fatal
1.....	3	2
2.....	2	0
3.....	9	4
4.....	14	3
5.....	16	3
6.....	18	9
7.....	16	1
8.....	15	2
9.....	22	3
10.....	13	0
11.....	20	10
12.....	16	2
13.....	12	2
14.....	25	5
15-19.....	40	14
20-29.....	27	4
30-.....	12	14
	280	78

TABLE VI
SYMPTOMS AND SIGNS IN 222 NONFATAL EPISODES

	Number	Per Cent
Pain in:		
Right chest.....	127	58
Left chest.....	74	33
"Chest".....	3	1
Epigastric.....	3	1
Low back.....	2	1
Substernal.....	4	2
Unrecorded.....	9	4
	222	100%
Hemoptysis.....	97	44
Friction rub.....	68	31
Effusion.....	43	19
Dullness.....	112	54
Positive roentgenogram.....	113	54

minutes, three-fourths died in less than half an hour, and only 10 per cent lived more than an hour. Theoretically, it would be possible to operate upon a fourth of the cases. Less than half of these could have the services of a Staff Surgeon under ordinary circumstances, since 44 of the 78 fatal episodes took place during "off hours."

Effect of Treatment.—The possibility of utilizing heparin to prevent

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thrombosis received early consideration at the Henry Ford Hospital. In 1924, Mason^{4, 5} used the drug in transfusions, and demonstrated that suitable doses gave protection against the clotting of blood which followed the intravenous injection of cephalin into experimental animals. He stated: "If clinical throm-

TABLE VII
INTERVAL BEFORE DEATH IN FATAL CASES

	No. of Cases
Less than 5 mins.....	18
5-9 mins.....	16
10-14 mins.....	8
15-29 mins.....	14
30-39 mins.....	13
1-3 hours.....	2
3-12 hours.....	1
12-24 hours.....	1
More than 24 hours.....	1
Not stated.....	4
	78

TABLE VIII
TIME OF DAY OF FATAL EPISODES

	No. of Cases
<i>"Office Hours"</i>	
9:00 A.M.-12:00 noon.....	13
12:00 noon-3:00 P.M.....	12
3:00 P.M.-6:00 P.M.....	9
	34
<i>"Off Hours"</i>	
6:00 P.M.-9:00 P.M.....	10
9:00 P.M.-12:00 midnight.....	13
12:00 midnight-3:00 A.M.....	7
3:00 A.M.-6:00 A.M.....	8
6:00 A.M.-9:00 A.M.....	6
	44

TABLE IX
RESULTS OF TREATMENT OF NONFATAL EMBOLISM

Year	Number of Operations	Nonfatal Embolism	Treated Cases			Fatal Embolism	Fatal with Treatment
			Heparin	Dicumarol	Ligation		
1939.....	5106	21	7	—	—	4	0
1940.....	5835	19	15	—	—	5	1
1941.....	6148	30	23	—	—	3	1
1942.....	6340	17	5	7	2	5	0
1943.....	6175	9	—	7	—	8	0
1944.....	7452	6	1	2	3	5	0
	37,056	102	51	16	5	30	2

bosis and embolism are comparable with experimental thrombosis and embolism, the anticoagulant offering so effective protection in one should be of use in the other." Doctor McClure relates that three of his patients were treated with material furnished by Mason, but the crude product available at

that time produced such untoward reactions that its use was discontinued. When purified heparin became available in 1939, it was used extensively in patients showing thrombotic manifestations. This experience has been presented in several reports.^{6, 7, 8} Other specific measures to be adopted were dicumarol administration and femoral vein ligation.⁹ One group of post-operative patients has received special attention. These are the individuals who have had a nonfatal infarction, thus, indicating the presence of dangerous thrombosis. Twenty of the 78 fatal cases had a previous nonfatal episode. This number added to 202 (number of surviving patients) gives a total of 222 nonfatal episodes. Seventy-two of these received treatment, and two of these died, giving a mortality rate of 2.8 per cent. On the other hand, 18, or 12.1 per cent of the untreated cases, died. At the Mayo Clinic,¹⁰ it was found that 18.5 per cent of patients with pulmonary infarct subsequently had a fatal embolism if no treatment was given. In a group of 63 such patients treated with heparin, there were only two deaths (3.2 per cent).

If treatment is so effective, why does not Table I indicate a decreasing incidence of fatal embolism instead of showing a plateau? This question may be answered by the data presented in Table IX, and a brief analysis of the fatal cases during the past six years.

The 30 fatal cases since 1939 had the following operations: Fracture of the neck of the femur, with or without nailing (five cases), hysterectomy (three cases), partial gastrectomy (three cases), cholecystectomy (five cases), hernia repair (three cases), appendicectomy (three cases), radical mastectomy (two cases), prostatectomy (two cases), partial resection of bladder, abdominoperineal resection of rectum, spinal fusion, and phlebitis (no operation). There was no apparent warning in 25 cases, hence, they received no special treatment. Two of the remaining five cases did receive treatment but died in spite of it; one of these had a partial gastrectomy and the other an operation for perforated appendix. Each had a second and fatal embolism on the second and seventh days, respectively, of heparin therapy. One patient who had had a prostatic resection for carcinoma had a nonfatal infarct and was scheduled for femoral vein ligation. He was inadvertently given an enema in preparation for this operation and expired with massive embolism while expelling it. The mere diagnosis of phlebitis in one patient should have indicated active measures against embolism—femoral vein ligation might have saved him. The fifth and last patient to be accounted for had been operated upon for hernia, and a warning pulmonary infarct had occurred. Although no purified heparin was on the market in this country at that time (1939), arrangements were being made to obtain some from Toronto. However, the patient (a doctor) was opposed to the new and relatively untried treatment and while deliberations were proceeding, a second embolism caused his death.

In retrospect, what could have been done to avert catastrophe in the 25 patients who expired without warning? Routine anticoagulant therapy should be considered. However, even if such treatment gave 100 per cent protection, it would have been necessary to heparinize or dicumarolize 3,900 patients

to prevent the three appendectomy deaths. The hemorrhagic complications in such a series would undoubtedly be notable. The plan is even less attractive when it is remembered that one of the appendectomy cases was lost in spite of heparin treatment. More care in looking for local signs of thrombosis in the legs and carrying out femoral ligation promptly, when indicated, should be of value. In this connection it should be pointed out that the figure of five for femoral vein ligation in Table IX represents only a fraction of those operations which have been performed during the past three years. The cases which had early ligation never had any kind of embolism, and, hence, were not included in the tabulation. However, since dangerous thrombosis can occur without producing signs or symptoms, even the extensive use of femoral vein ligation leaves many patients unprotected. A prophylactic procedure which can be easily applied to all, or nearly all, operations is needed. Early ambulation may be the answer. Many surgeons are getting their patients up on the first day and are noting an absence of embolic complications. If incisions have been properly placed and nonabsorbable suture material has been used, it should be perfectly safe for patients who have had appendectomy, hernia repair, cholecystectomy, gastrectomy or hysterectomy to be up on the afternoon of operation. It will be noted that 17 of the 25 cases under discussion had the operations just enumerated. It may be that fractures of the femoral neck, prostatectomies, radical mastectomies, spinal fusion and resections of the rectum will require some modification of the early ambulation program. It is probable that even these patients can be protected by appropriate means.

SUMMARY AND CONCLUSION

A study has been made of the fatal and nonfatal embolic complications which occurred in a series of over 100,000 operations. Predisposing factors have been noted with regard to age, sex and the type of operation. Since the adoption of anticoagulant therapy and prophylactic femoral vein ligation, there has been a very low mortality rate in cases selected for treatment. However, these measures have not prevented a number of sudden and unexpected fatal embolisms. Early ambulation offers the most promise as a preventive measure easily applicable to the majority of surgical patients.

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CONGENITAL CYSTIC LUNG

SUCCESSFUL PNEUMONECTOMY IN A THREE-WEEK-OLD BABY

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CYSTIC DISEASE OF THE LUNG occasionally appears as a consequence of inflammatory reactions. Cicatricial tissue around bronchi, bronchioles, and alveolar ducts can produce obstructive emphysema of a bullous type, so that cavernous spaces of considerable size develop in the pulmonary parenchyma. When examined roentgenologically, such a lung will show the mottled and increased density of pulmonary infection and, in addition, will indicate the interspersed cystic areas. If the patient is seen for the first time at this early stage, it is impossible to determine whether the cysts are of congenital origin and the infection superimposed thereon, or whether the cysts are the product of the pneumonitis. If such a patient survives for a protracted period—as is frequently the case—the more active portions of the inflammation can disappear and give little or no shadow in the roentgenogram, whereas some persistent scarring can maintain the cystic process. Hence, at a late stage the postinfectious origin of the cysts can be appreciated only if a history of pneumonitis is obtainable or if the lung comes to microscopic examination by a competent pathologist.

Lung cysts may also be of congenital origin, though these are probably less common than the acquired form. There have been adequate descriptions of specimens which have been removed surgically or which have been found at autopsy. Such an abnormality of the lung may arise as a solitary, globular structure from an accessory bronchial bud and thus appear as a pedunculated, balloon-like affair, situated between pulmonary lobes or else projecting in front of or behind the lung root. More frequently, cysts develop within the lung substance and under such circumstances they are quite apt to be multiple. The lining membrane is composed of a bronchial epithelium, the individual cells of which are mucous-secreting, ciliated, and columnar in type. This histologic feature positively identifies the cyst as being congenital in origin. Beneath the lining membrane there may be a thin layer of smooth muscle and possibly bits of irregularly placed cartilage. There may or may not be some superimposed infection. Congenital lung cysts are occasionally bilateral, but fortunately they are more often limited to one lung.

Some congenital cysts of the lung have little clinical significance. If they do not become infected and if they are small enough to leave the physiology of the lung undisturbed, their existence is of little more than academic interest. Their presence may be incidentally discovered by roentgenologic examination of the chest; they can persist for many years with no ill effects on the patient's

health. However, not all congenital cysts run a benign course; they may give rise to complications, principally of two sorts. In the first, infection of the cyst wall or suppuration within its lumen may be extensive and serious. In the second, the cyst (or cysts) is connected to the respiratory tract by a relatively small or angulated passageway, so that air enters and becomes entrapped within the cavity. Thus, a positive pressure can be built up within the cyst (or cysts) so that the structure becomes greatly distended and compresses adjacent lung tissue, and possibly displaces the mediastinal organs to the opposite side of the chest. Hence, it is obvious that respiratory distress can be extreme, and indeed the situation may be incompatible with life unless some form of relief is promptly instituted.

Respiratory embarrassment from increased tension within lung cysts could be relieved in one of several ways:

1. A needle can be passed through the chest wall and into the cyst cavity—permitting quick withdrawal of entrapped air. Resulting improvement in the patient's condition is apt to be immediate and dramatic, but is only temporary since air will almost certainly reaccumulate. Furthermore, a puncture of the cyst wall is prone to allow subsequent escape of air from the cyst into the pleural space—thus, complicating the general picture in the ensuing few hours. Without doubt, aspiration of a distended cyst may be a life-saving procedure, but it should be done only with a very fine-bore needle and probably should be employed only as a temporizing measure while preparing for a more adequate treatment of the lesion.

2. A trocar can be introduced through the chest wall and into the cyst so that a catheter may be threaded into it for establishment of prolonged aspiration. In this form of treatment, it would be preferable to employ a small mushroom catheter, so that its bulbous end could be pulled up against the inside of the cyst wall and prevent escape of air into the pleural space. Constant application of suction to the catheter should keep the cyst completely collapsed—even for a protracted period—and this should be of value while preparing for more extensive surgery. It is tempting to think that congenital cysts might be sclerosed by introduction of appropriate fluids through a catheter, but the communication with a bronchus would obviously preclude such therapy.

3. Marsupialization of the cyst onto the chest wall and destruction of its lining membrane by curettage, cauterization, or packing has many points in its favor as a method of treatment. However, an external opening introduces a considerable hazard, because infection might gain entrance to the regional lung substance and this might be difficult to control. The greatest objection to the method is the fact that congenital lung cysts are prone to be multiple and, hence, the treatment of one cyst—even though successful in obtaining its obliteration—is apt to be followed by the subsequent formation of additional cysts in the nearby lung tissue. Hence, marsupialization should be practiced only when the surgeon is quite sure that he is dealing with a solitary cyst.

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4. Enucleation of a pulmonary cyst, or removal of pulmonary tissue containing it, is by far the treatment of choice. The extent of the cystic disease will determine how extensive a resection of lung substance will be required. Local resection, lobectomy, or even pneumonectomy may be necessary. In general, as much lung tissue as possible should be saved, but an adequate margin must be removed to insure complete removal of all abnormal structures.

In the case herein reported, a left total pneumonectomy was performed for respiratory distress resulting from congenital cystic disease of the lung. Though the baby was but 23 days of age, and weighed only 6 lbs. 4 oz. (2.8 kilos), the operation was tolerated in a surprisingly satisfactory manner. Likewise, the postoperative recovery was prompt, uncomplicated, and most gratifying.

Case Report.—W. W. was a three-week-old, male infant, who entered the hospital, December 7, 1944, having been referred by Dr. Eli C. Rodman. On the fourth day of life the child was noted to be breathing in an abnormal and slightly labored way, but there was no cyanosis. During the following days the respiratory rate was known to be definitely elevated, and this symptom gradually increased in severity. On the day of hospitalization dyspnea had become quite pronounced, and the child was moderately cyanotic. On examination by the family physician, the color was found to be poor, the breathing was very rapid, and the pulse was quite fast. Immediate hospitalization was recommended.

Physical examination showed the following points: The weight was 6 lbs. 4 oz. The temperature was normal. The baby tended to lie with his head thrown back, and was obviously using the accessory muscles of respiration. The alae nasi dilated during respiratory efforts. The color was fairly good, except during periods of straining and crying when there was moderate cyanosis. The respiratory rate was counted at 110-120, the pulse was 140 per minute. There was no percussible area of cardiac dullness on the left. Lateral to the right lower border of the sternum there was dullness, which presumably represented a dextro-position of the heart. This observation coincided with the finding of normal cardiac sounds to the right of the sternum and only very faint sounds to the left of the sternum. The respiratory excursion of the left side of the chest was diminished as compared to that of the right. There was slight intercostal and supra-clavicular retraction over the right side of the chest. There was increased resonance over the left lung anteriorly and posteriorly, with apparently normal resonance over the right lung field. The breath sounds over the entire left lung were extremely faint. Over the right lung the breath sounds were of normal quality.

Roentgenologic examination of the chest showed the left hemithorax to be increased in volume, with depression of the left dome of the diaphragm. Within the left lung substance there appeared to be a large, air-containing sac with a thin and sharply outlined, smooth wall (Fig. 1). This cystic structure occupied a large part of the left hemithorax, but there was some compressed lung tissue at the left base and at the left apex. Some of the left lung appeared to be herniated across the midline of the chest. The mediastinum was markedly shifted toward the right, the heart was in a dextro-position, and the right lung was considerably compressed. The findings suggested a cavity within the left lung which was filled with air under positive pressure. In order to rule out a left diaphragmatic hernia, a swallow of barium was given and appropriate films excluded any possibility of such a malformation.

Course: Because of the marked respiratory distress and the intermittent cyanosis, the child was placed in an oxygen tent, and carefully observed for a period of 24 hours. The respirations were slightly improved with the administration of oxygen and diminished to 90-100 per minute. For the most part, the cyanosis was fairly well-controlled, though

at times the baby was dusky, particularly during episodes of squirming, straining or crying. It became clear that air had become entrapped under positive pressure within the cyst of the left lung and that some form of mechanical relief was essential. Needling of the cyst was avoided, because of the belief that its beneficial effects would be temporary, and that it would be accompanied by the danger of allowing air to escape into the pleural cavity, which might thus complicate the general situation.

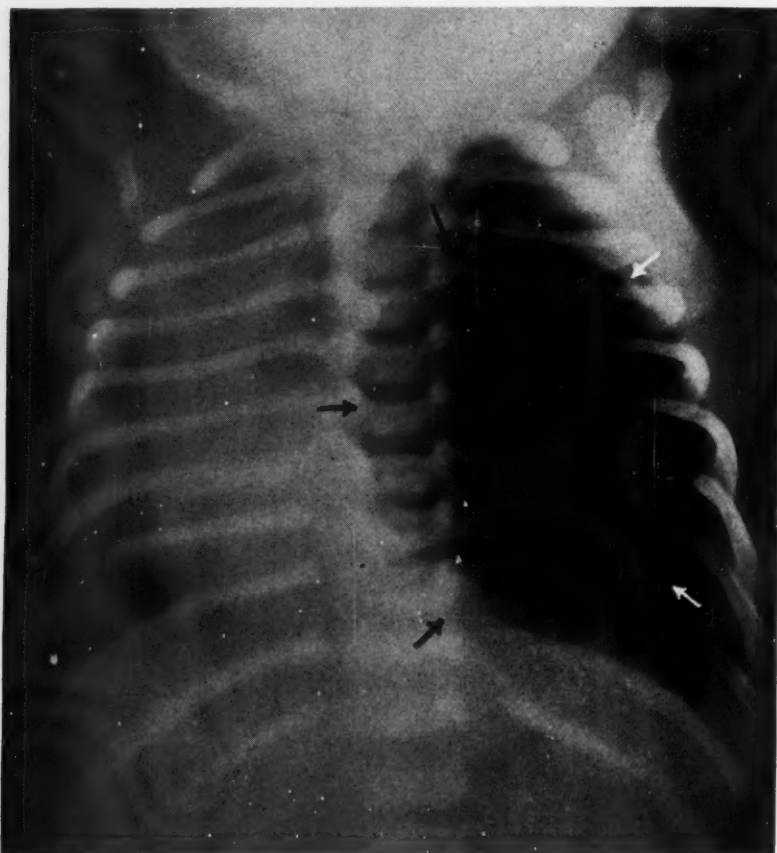


FIG. 1.—Preoperative roentgenogram of the chest, showing large cyst in the left lung, marked displacement of the heart to the patient's right, and compression of the right lung. (Cyst indicated by arrows)

Operation was decided upon, with three general plans of therapy in mind: 1. If the cyst should be found arising from a separate bronchial stalk and lie outside of pulmonary tissue, amputation of it should be relatively simple and effectual. 2. If the cyst lay within one lobe of the lung, this entire lobe could be sacrificed and lobectomy would be the method of choice. 3. If the cyst lay within the left lung so that it involved its hilum, then the entire lung would be removed. It was definitely decided before operation that no attempt would be made to peel out a lung cyst which might reside within pulmonary substance, since such a dissection would lead to extensive hemorrhage or would be followed by multiple bronchial fistulae, empyema, or uncontrollable pneumothorax. It was our conviction that any such dissection of a cyst out of lung tissue would entail an operative procedure of too great magnitude for a tiny and seriously ill baby.

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Operation: With a tightly-fitting face mask, and without a laryngeal tube, cyclopropane anesthesia was induced, and was tolerated extremely well. A left anterolateral thoracotomy was performed in the fourth interspace. The opening of the chest was extremely simple; it was not necessary to remove any rib or to cut the costal cartilages, since the bony and cartilaginous structures in the infant were so soft and yielding that the insertion of a self-retaining retractor permitted an adequate exposure. The normal lung contour was altered by the presence within it of a golf ball-sized, air-filled and tense cyst which lay largely within the lower part of the upper lobe but which extended well into the hilum of the lung. The left lower lobe was compressed and atelectatic, as was the apex of the upper lobe. Situated around the periphery of the main cyst, particularly toward its superior border, there were several smaller cysts, 2-4 mm. in diameter. Two things seemed evident: First, that the main cyst was so large and extended so far into the root of the lung that it would be impossible to perform an upper lobectomy without damaging the root of the lower lobe. Second, that any removal of the main cyst (even though this might be feasible) would still leave some of the tiny cysts in adjacent lung tissue which might conceivably develop at a subsequent time and give further trouble. Total pneumonectomy was, therefore, decided upon. The cyst was deflated with an aspirating needle; this greatly facilitated the subsequent steps. There were no pleural adhesions over any part of the lung surface. The pneumonectomy was performed with ease since there was no inflammatory reaction in the root of the lung, and the dissection could be carried out quickly. Individually, arteries and veins were doubly tied with No. 00000 Deknata silk and were divided. The left main bronchus was doubly clamped and then divided between these instruments. The bronchial stump was sewed over-and-over with a continuous No. 00000 Deknatel silk which was carried on a small, atraumatic needle; this gave a satisfactory and tight closure. Flaps of parietal pleura were now mobilized anteriorly and posteriorly and brought together with interrupted fine silk sutures so as to cover over and completely bury the bronchial stump within the mediastinum. A small urethral catheter was placed within the pleural cavity and the chest was closed with continuous No. 000 chromic catgut to the intercostal muscles and continuous No. 0000 chromic catgut to the severed pectoral muscles. Interrupted silk sutures were placed in the subcutaneous tissues and skin. Just before the last cutaneous sutures were placed, suction was applied to the indwelling catheter and all air was sucked out of the left pleural cavity. The catheter was then quickly withdrawn and the remainder of the skin was tightly closed. The infant stood this procedure quite well, but was given a transfusion of 40 cc. of citrated blood at its conclusion.

Postoperative Course: Following operation the child was replaced in an oxygen tent for 24 hours. On the evening of the day of operation, sips of saline and glucose were given by mouth, and were retained. On the following day oral feedings were started, providing about half of the normal caloric and fluid requirements. At the end of 48 hours the child was taking full feedings by mouth without any difficulty. The color was good throughout the postoperative course, except for a period of several hours on the sixth day when the oxygen tent was temporarily resumed. The general vigor of the baby during the postoperative course was extraordinary. The temperature rose to 101° F. (rectal) 24 hours after operation, but gradually subsided to normal by the fifth day. The respiratory rate was elevated to 60 or 70 per minute, but gradually diminished during the following ten days to a level of 50 or 60, with occasional peaks to 65. Following operation the baby was given intramuscular injections of penicillin, totaling 32,000 units per 24 hours, for seven days. The chest wound healed *per primam* (Fig. 2). There was no evidence of empyema or bronchial fistula at any time. A moderate amount of fluid accumulated in the left pleural space, but this was not sufficient to require tapping of the chest. The weight-gain was satisfactory and progressive. The weight upon admission had been 6 lbs. 4 oz.; it rapidly increased to 7 lbs. 6 oz. at the time of hospital discharge, on the fifteenth day.

For the first few days after operation the superficial veins over the right side of the scalp and the right side of the neck were distinctly distended when compared to their preoperative condition and to the postoperative condition of the left side of the head, neck, and shoulder. Presumably the postoperative shift in the mediastinum had angulated and partially obstructed the veins as they entered the right side of the upper thorax. This superficial venous congestion gradually diminished, and by the end of six days had entirely disappeared.



FIG. 2.—Photograph of baby on tenth postoperative day, showing primary healing of chest wound.

During the seven months that the baby has been followed since hospital discharge, there has been no evidence of embarrassment by loss of the left lung. The child's color has constantly remained good; the respirations have been quiet and unlabored. The baby feeds normally and appears to be a bright, active, and normally developing infant. At six months of age the weight was 15 pounds. Figure 3 shows the excellent general condition of the child at that time. Repeated examinations since operation have shown the heart well out to the left side of the chest and the apex beat can be felt and heard in the left axilla. Roentgenologic examinations have shown the mediastinum shifted to the left, so that the right lung has been satisfactorily aerated. Films have shown some fluid in the left pleural space, which has gradually disappeared over the course of a few months. Figure 4 indicates the roentgenologic findings six months after operation. Because of fear that deformity might follow in the chest of such a young child after a complete pneumonectomy, particular attention has been paid to the development of the thoracic cage. The respiratory movements have obviously been more marked on the

CONGENITAL CYSTIC LUNG

right than on the left, but the thorax appears to be reasonably symmetrical and there is no important scoliosis of the spine.

Pathologic Examination.—Dr. Sidney Farber and Dr. James Arey: The lung contained an almost spherical cyst, approximately 5 cm. in diameter, which replaced most of the left upper lobe and which greatly compressed the lower lobe. Scattered around the periphery of this were multiple small cysts, each a millimeter or two in diameter. After fixation in formalin, the lung was sectioned and the general findings indicated in



FIG. 3.—Photograph of baby six months after operation. There is no apparent deformity or asymmetry of the chest.

Figure 5 were noted. The main cyst was lined by a thin, but rather tough layer, which was thrown up into a few low trabeculae. Several tiny, pinpoint openings led out of the main cyst into some of the smaller cavities previously described in the adjacent upper lobe substance. No cysts were found in any part of the lower lobe. A tiny hairpin probe could be passed by a tortuous route from the main cyst into the upper lobe bronchus.

Microscopically, the wall of the large cyst was found to be lined by ciliated, columnar epithelium, supported on an abundant, loose, connective tissue base (Fig. 6). Surrounding this were scattered bundles of nonstriated muscle. In some areas, islands of cartilage could be demonstrated in the wall of the major cyst. In a few places, some mucous-secreting glands lay deep in the wall and were scattered through and outside of the smooth muscle layer. Some sections showed the tiny, secondary cysts around the periphery

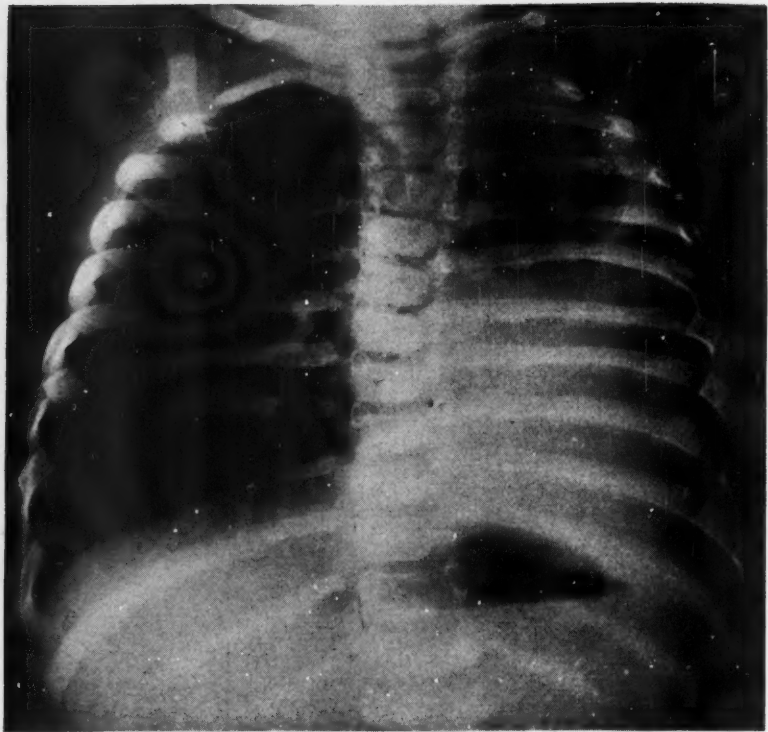


FIG. 4.—Koentgenogram, six months after operation. The heart is drawn to the left side of the chest. The upper part of the right lung has ballooned over into the apex of the left pleural cavity.



FIG. 5.—Photograph of sectioned lung, with large, central, congenital cyst.

CONGENITAL CYSTIC LUNG

of the main cavity, from which they were separated by the smooth muscle layer. These were, likewise, lined by a ciliated, columnar epithelium, and in some instances a direct communication could be demonstrated with the large main cyst (Fig. 6A). Other sections taken from the upper lobe showed additional small, congenital cysts, the openings of which could not be found. This cystic change through the pulmonary tissue was much more extensive than had been suggested by the gross appearances of the specimen. Some of the sections showed mild edema or extravasation of red cells into alveolar tissue of the surrounding lung, which were probably secondary to the trauma of oper-

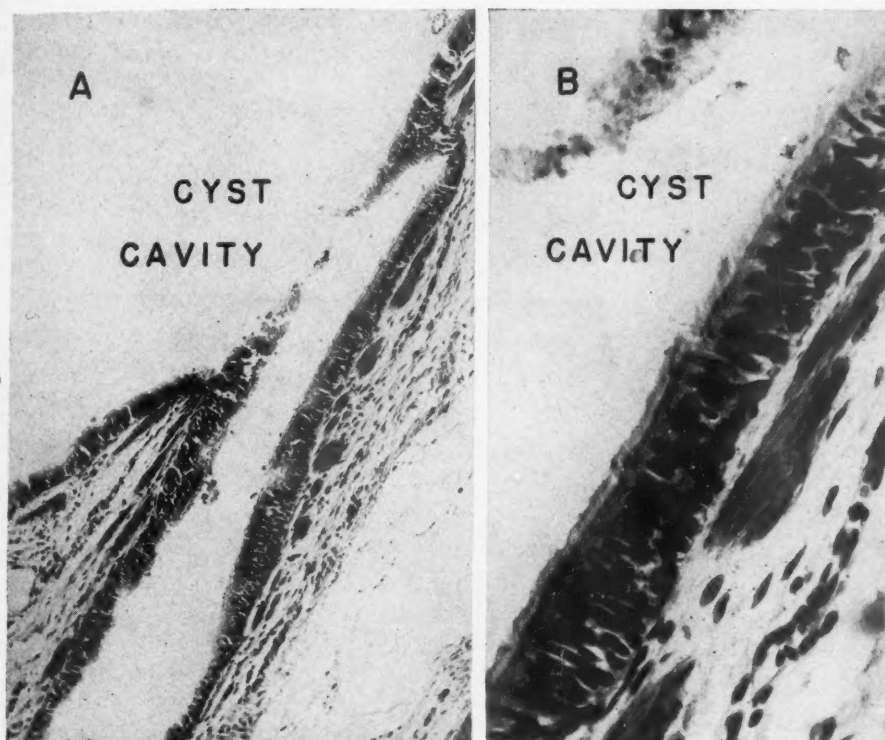


FIG. 6.—A. Low power photomicrograph showing cyst lining and the opening to a secondary cyst. B. Higher magnification, showing ciliated columnar epithelium, from the main cyst wall.

ation. There was no important inflammatory change in any of the material which was studied.

SUMMARY

A brief report is made of a three-week-old baby with congenital cystic disease of the left lung, who was treated by total pneumonectomy. In spite of the child's small size, he withstood the operation in a very satisfactory manner and has had an uncomplicated postoperative course.

DELAYED INTERNAL FIXATION OF COMPOUND BATTLE FRACTURES IN THE MEDITERRANEAN THEATER OF OPERATIONS

CASE HISTORIES WITH ILLUSTRATIONS
A FOLLOW-UP STUDY IN THE ZONE OF INTERIOR

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PART II

THE CASE REPORTS are presented to illustrate the classifications of indications and results as they are compiled in the tables of data. While the reports have been made brief, the principles of reparative surgery of compound fractures including those for the use of delayed internal fixation are illustrated frequently.

Case 1* (see Plate I)

Indication—Obligate-1: Bone loss producing a segmental defect.

Result—A: The fracture united and the wounds healed, without sequestration or removal of metal.

Diagnosis: 1. Fracture, compound, comminuted right humerus lower part of mid-shaft, with segmental loss of bone. 2. Laceration of median and ulnar nerves.

Wounded: October 20, 1944, missile—not recorded.

Reparative Surgery: On November 1, 1944, additional devitalized tissue including several totally loose bone fragments was excised. A manual effort to reduce the fracture and hold it by a spica encasement was unsuccessful.

On November 12, through the unsutured compounding wound, the ends of each fragment were squared to maximize the surface for bone contact, which was achieved by fixation with three wire loops. The resultant shortening was about two inches. A pressure dressing held soft-parts partially over bone but suture was not performed.

On November 20 the wound was partially sutured and a skin flap was rotated so as to cover all denuded bone. He was evacuated to the Zone of Interior in early December, in a "hanging cast."

Zone of Interior Record: On arrival, all bone was covered, but there was an unhealed granulating area. The wound healed and the fracture united promptly without sequestration or removal of metal.

* This patient was managed by Major Herbert W. Harris.

COMPOUND BATTLE FRACTURES

PLATE I



PLATE I.—Case 1: A. A. P. view on admission to Base Hospital. Note bone loss and defect.
B. Lateral view on admission to Base Hospital. Note bone loss and defect.
C. A. P. view after fixation.
D. Lateral view after fixation.
E. A. P. view after bony union and wound healing, without sequestration or removal of metal.
F. Lateral view after bony union and wound healing, without sequestration or removal of metal.

Case 2* (*see Plate II*)

Indication—Obligate-1: Bone loss creating a segmental defect of bone, without contact of fragments.

Result—E: The fracture did not unite but the wound healed, without sequestration or removal of metal.

Diagnosis: 1. Fracture, compound, comminuted right humerus, with loss of bone.
2. Laceration of radial nerve.

Wounded: May 6, 1944, by high explosive shell fragments.

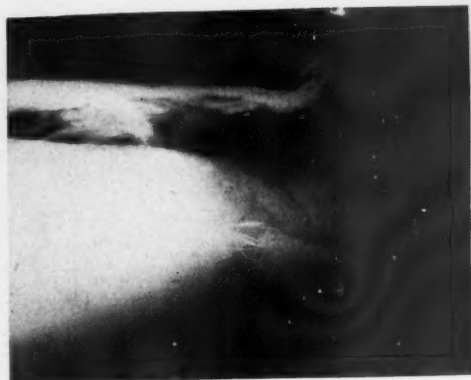
Reparative Surgery: About May 14th a septic compounding wound was revised, excising the residual dead tissue. A segmental bone defect was present. The fragments were approximated by two wire loops. The severed radial nerve was located, approximated by a single suture, and transplanted to a bed in healthy muscle. Muscle was sutured so as to cover all denuded bone and the nerve. The skin was partially closed. The wounds healed. On July 13th he was evacuated to the Zone of Interior in a shoulder spica.

Zone of Interior Record: On admission, all wounds were healed. The fracture did not unite. On January 23, 1945, bone grafting of the humerus and definitive suture of the radial nerve were performed. The wire loops were removed at that time.

* This patient was managed by Major Joe M. Parker and Lt. Col. Henry G. Schwartz.

COMPOUND BATTLE FRACTURES

PLATE II A



B



C

PLATE II.—Case 2: A. A. P. view—15 July, 1944—in the overseas hospital.
B. Lateral view—15 July, 1944—in the overseas hospital.
C. Lateral view—19 January, 1945—showing the nonunion.

Case 3* (see Plate III)

Indication—Obligate-1 and 2: Distraction and failure to achieve reduction.

Result—B: Fractures united and after removal of sequestra and metal the wounds healed.

Diagnosis: Fracture, compound, comminuted distal third, left radius and ulna.

Wounded: May 31, 1944, by high explosive shell fragments.

Reparative Surgery: Partial wound closure and manipulative reduction, about June 10, were not successful. Necrotic bone presented itself in the septic wound. On August 12, 1944, the necrotic bone ends were excised back to bleeding bone, the fragments of each bone were approximated and fixed in reduction by plates. The resultant shortening from bone loss and death of bone was about three inches. The wounds were closed with drainage.

Zone of Interior Record: On admission, October 22, 1944, the wounds were draining but the fracture site was stable and was uniting. On December 7, 1944, sequestra and the metal were removed, after which the wounds healed promptly. Plastic tendon surgery was planned.

* This patient was managed by Major Allen Collom.

COMPOUND BATTLE FRACTURES

PLATE III



PLATE III.—Case 3: A. A. P. and lateral views, 14 July, 1944—five weeks after plating.
B. A. P. view—18 September, 1944—five weeks after plating.
C. Lateral view—18 September, 1944—five weeks after plating.
D. A. P. and lateral views, 6 January, 1945. The fractures are united and the wounds are healed.

Case 4* (see Plate IV)

Indication—Obligate-2 and 1: Failure to obtain reduction by other measures (traction) plus persistent distraction. (Fixation in presence of established sepsis.)

Result—A: The fracture united in anatomic alignment, and the wounds healed without sequestration or removal of metal.

Diagnosis: 1. Fracture, compound, comminuted left femur midthird. 2. F. C. C. left patella with septic knee joint (not here considered).

Wounded: February 16, 1944, by multiple high explosive shell fragments.

Base Hospital Record: On admission, February 20, all wounds were septic. Additional devitalized tissue was excised, the wounds were left open, femoral skeletal traction was instituted. The fracture distracted and sepsis continued. From February 20 until March 14 he received 3,000 cc. of whole blood.

Reparative Surgery: On March 15 (he received 2,000 cc. of blood that day) fascial plane and fracture site abscesses were drained, totally loose bone fragments were removed and the fracture was stabilized in reduction by a long bone plate. Sufficient wound closure was done to cover all exposed bone. Six days later additional closure and appropriate knee joint surgery were performed. There was intermittent drainage from the most proximal dependent portion of the drainage incision. He was evacuated to the Zone of Interior in May.

Zone of Interior Record: Following admission, considerable efforts were made to restore motion to the formerly septic knee. There was recurrent drainage from the wound for some weeks but thereafter the wound remained healed until November 30, when the scar was resected and, at the same time, the metal was removed. Some granulating tissue was curetted. Primary closure of the wound was successful. Brace-protected weight-bearing was instituted for several months. At present he walks with full weight-bearing, and all wounds are healed solidly.

* This patient was managed by Major Joseph Godfrey and Captain Russell Erickson.

COMPOUND BATTLE FRACTURES

PLATE IV

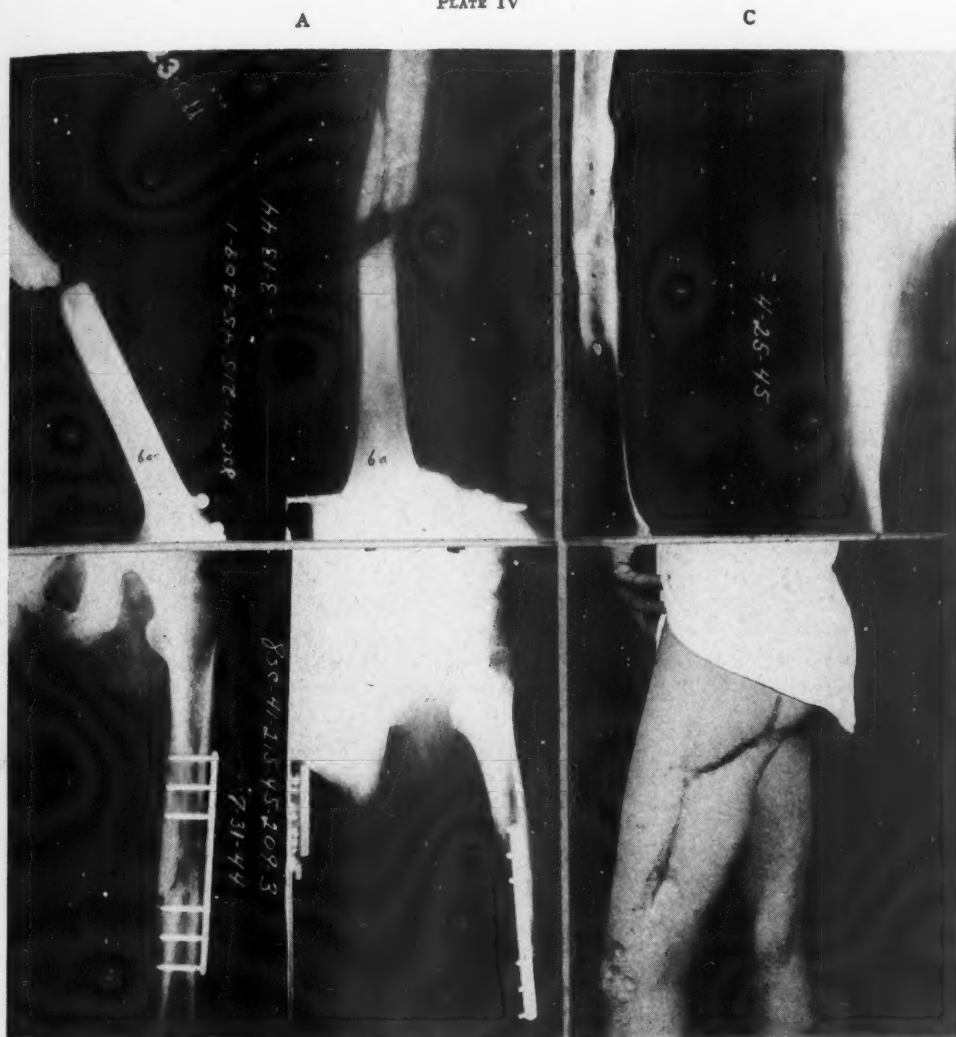


PLATE IV.—Case 4: A. A. P. and lateral views on March 13th, before reparative surgery, revealing the distracted fracture and gas abscesses in the fracture site and adjacent fascial plane.

B. The united fracture in the Zone of Interior Hospital—31 July.

C. The united fracture in excellent alignment, with metal removed—April, 1945.

D. The healed wounds, April, 1945.

Case 5 (see Plate V)

Indication—Obligate-2: Failure to achieve reduction by other measures—(established sepsis).

Result—B: The fracture united and following removal of metal and sequestra the wounds healed. Late refracture.

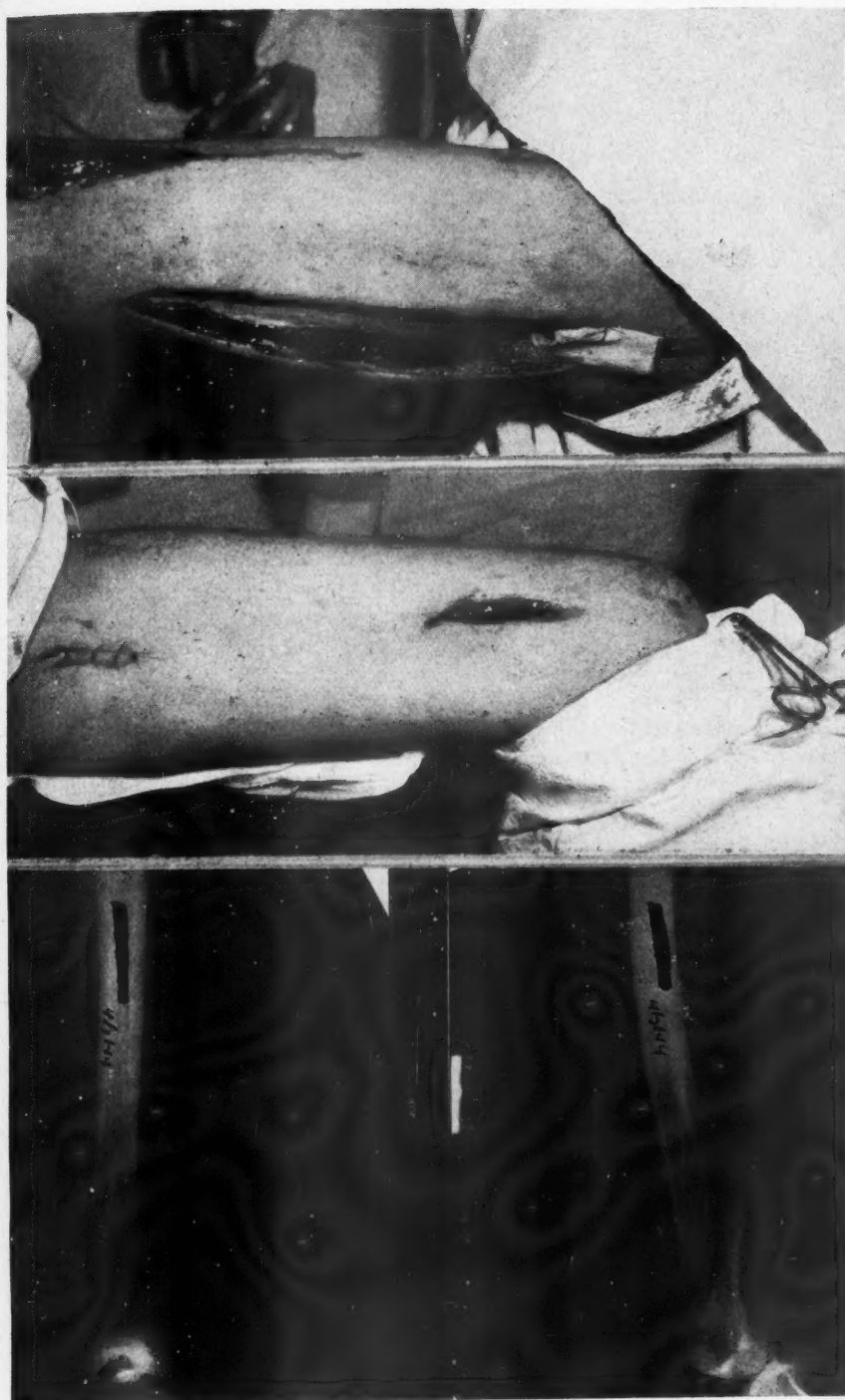
Diagnosis: 1. Fracture, compound, comminuted left femur lower third (septic).
2. Sepsis (low grade) left knee joint (not here considered).

Wounded: February 20, 1944, by high explosive shell fragments.

Base Hospital Record: On February 25 skeletal traction utilizing a wire in the tibial tubercle was instituted. The wounds were purulent at that time. Several incisions for drainage were made including one on the lateral side of the suprapatellar pouch. Pus pocketed in the proximal portion of the posterolateral fascial plane of the thigh.

Reparative Surgery: On March 31, the posterolateral plane was incised, draining the abscess and the fracture site. Pus which had tracked up the inner side of the thigh anterior to the adductor magnus was drained by an incision medially. There was no union of the fracture. The extremity was returned to skeletal traction.

PLATE V



A

B

C

PLATE V.—Case 5: A. The compounding wound, laterally, in the distal third and the drainage incision on 31 March.
B. The compounding wound, medially. A drain emerges from an incision at the extreme left hand edge, 31 March.
C. The unreduced fracture, 3 April.

Case 5* (Continued) (see Plate V Cont'd)

On April 6 the fracture was stabilized in reduction by four screws. At the same time the septic knee was cleaned of all necrotic cartilage (including the entire patella), irrigated and closed. The wounds were closed with drainage. There was moderate drainage from all wounds for several weeks but only granulating areas remained when a hip spica was applied on May 11 for evacuation to the Zone of Interior.

Zone of Interior Record: On admission, June 22, there was some drainage medially from the fracture site. On August 24 two sequestra and the screws were removed. The fracture was united but there was a defect in the anterior portion resulting from the bone loss at wounding. The wound healed promptly. In late December, the patient fell, sustaining an incomplete fracture across the site of bone loss. A long leg plaster was applied and he was sent home on furlough. He again fell, completing and displacing the fracture. When observed in March, 1945, the refracture, which is not in the plane of the original fracture, had not been reduced by skeletal traction. There was ten degrees of active knee motion.

* This patient was managed overseas by Major Joe M. Parker and Captain Richard Crouch.

COMPOUND BATTLE FRACTURES

PLATE V—(Continued)



D

D. Artist's conception of the surgery on 6 April.

PLATE V—(Continued)

E



F



G

- E. The almost healed lateral wounds, 3 May.
F. The almost healed medial wounds, 3 May.
G. A. P. view—27 May—before evacuation.

PLATE V—(Continued)

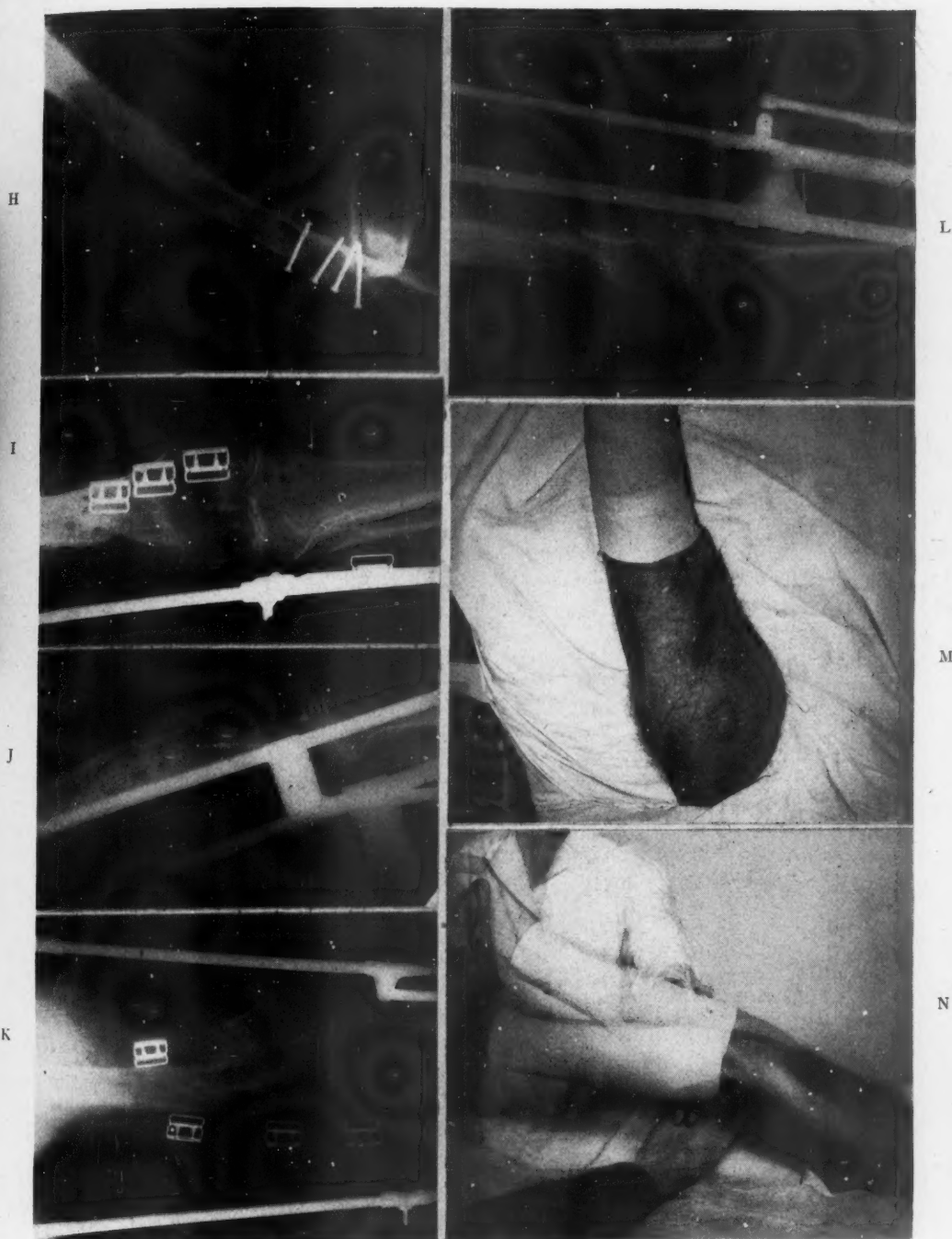


PLATE V. (Continued)—Case 5: H. Lateral view—27 May—before evacuation.
I. A. P. view. The united fracture after removal of sequestra and metal.
J. Lateral view. The united fracture after removal of sequestra and metal.
K. A. P. view of displaced refracture, February, 1945. Note transverse plane of fracture in contrast to original obliquity.
L. Lateral view after refracture, February, 1945. Note refracture point of original bone loss.
M. Healed medial wounds, March, 1945.
N. Healed lateral wounds, March, 1945. (The dark area is a recent superficial abrasion of old scar). The range of active knee motion, March, 1945.

Case 6* (see Plate VI)

Indication—Obligate-2: Failure to achieve reduction by other measures.

Result—C: The fracture is united solidly in excellent alignment, but the wound is unhealed (metal and an obvious sequestrum (roentgenographically) remain *in situ*).

Diagnosis: Fracture, compound, oblique, right femur upper third.

Wounded: October 2, 1944, by a high explosive shell fragment.

Reparative Surgery: Reparative surgery was delayed because of a large volume of casualties reaching this Base Hospital, located only a relatively few miles behind the fighting. Many required both initial and reparative surgery.

On October 21, 19 days after wounding, a wire was inserted through the lower femur. The fracture site was exposed by gentle retraction. The fragments were overriding about 1.5 inches, with interposed muscle. Manual skeletal traction established that reduction by balanced skeletal traction was quite doubtful. (Therefore, this case is classed as Obligate-2.) Through a posterolateral operative approach, the femoral fragments were freed and reduced with difficulty, and were stabilized in reduction by three screws. The compounding wound edges were excised. Neither wound was sutured. The extremity was placed in skeletal traction. On October 26, 1944, five days later, the patient was returned to surgery. Old blood clot and some tissue debris were cleaned from the wounds. Each wound was partially closed with separate drainage. The drains were removed five days later. Both wounds healed but, later, drainage recurred from the lateral wound. He was evacuated to the Zone of Interior in January, 1945.

Zone of Interior Record: Drainage has persisted from the old compounding wound, but the fracture united solidly, in good alignment. Roentgenograms, made in May, 1945, reveal an obvious sequestrum and absorption about the two screws. Following their removal, sound wound healing and an excellent end-result are anticipated.

* This patient was managed by Lt. Col. Roderick Begg and Capt. Edward Manning.

PLATE VI

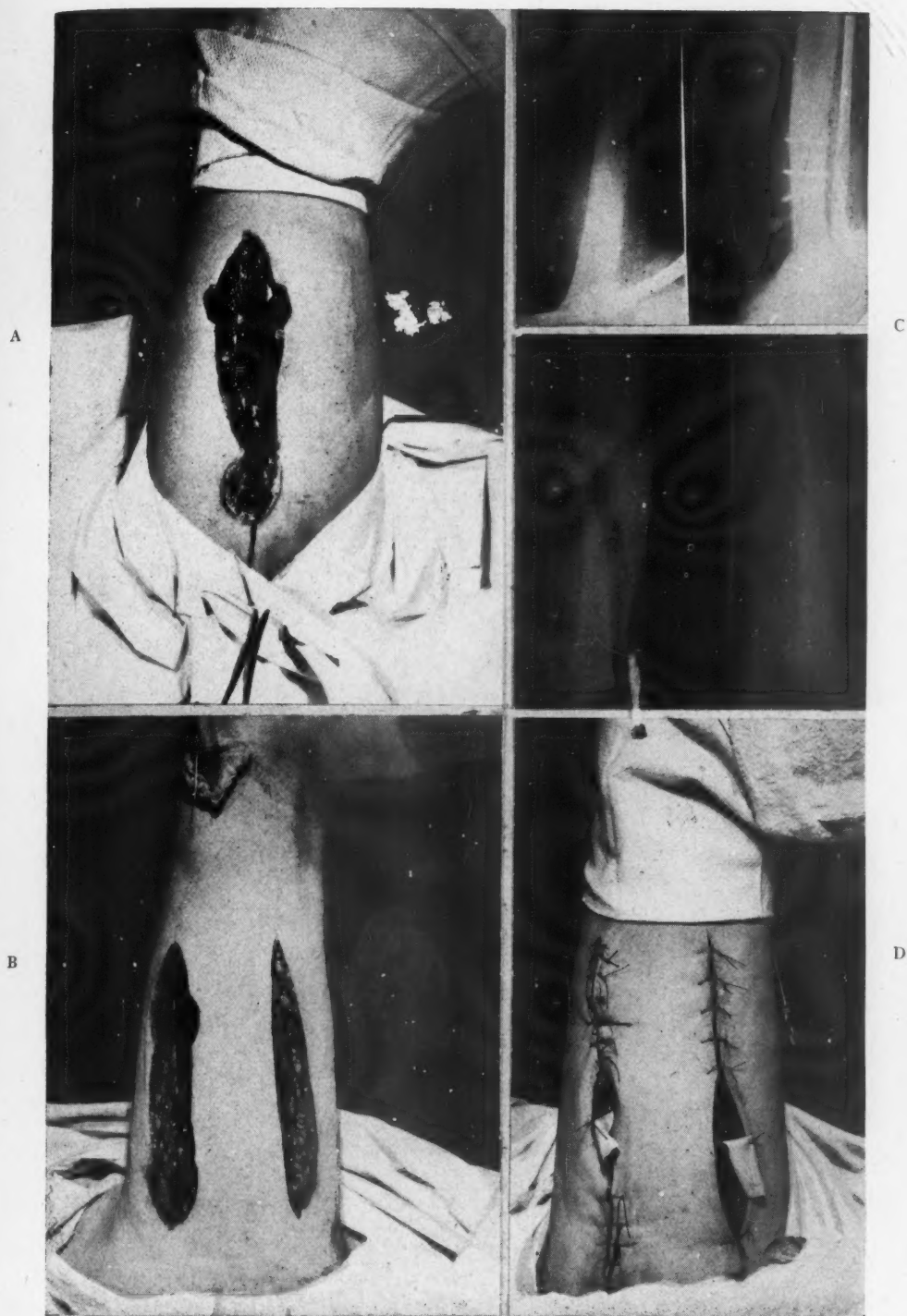
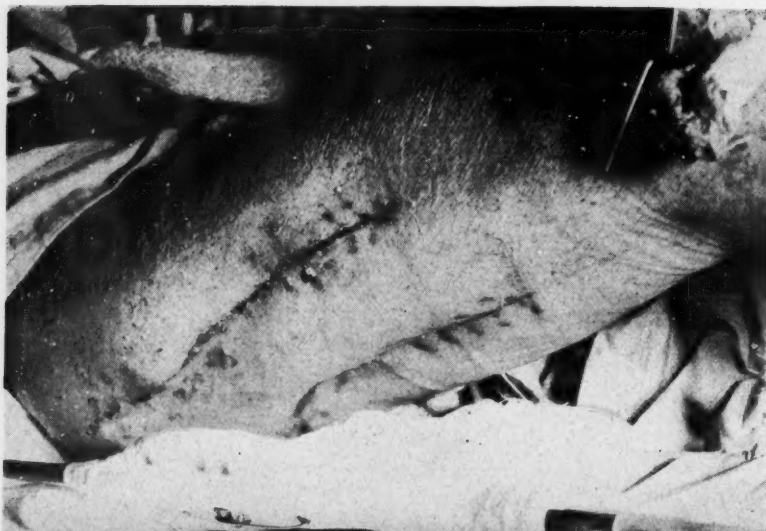
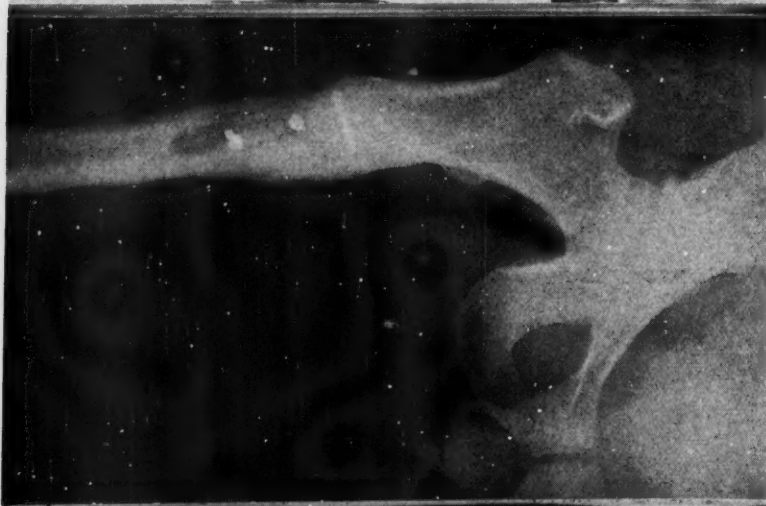


PLATE VI—Case 6: A. The old compounding wound in the operating room, 19 days after wounding.
 B. The excised compounding wound and the posterolateral operative approach at the completion of the internal fixation.
 C. Roentgenograms before and after fixation. The former are of films made soon after initial surgery and do not depict the shortening seen at operation.
 D. The partial closure of each wound 26 October, 1944. The drains are separate and not through-and-through.

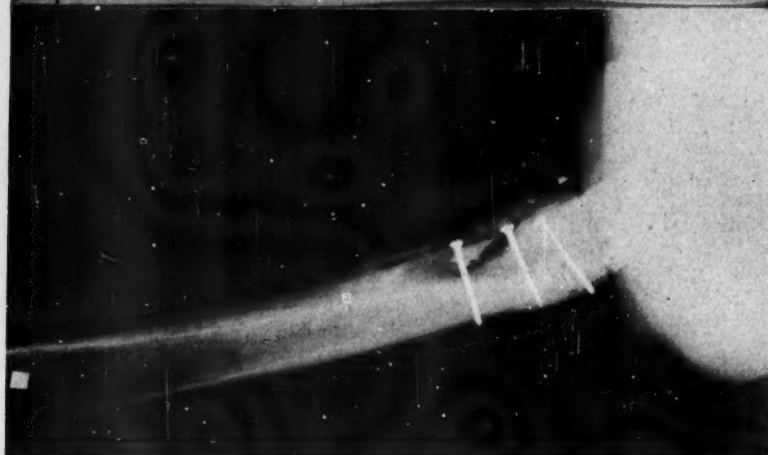
E



F



G



E. The almost healed wounds 15 November, 1944. Drainage recurred from the old compounding (lateral) wound.

F. A. P. view of the united fracture in April, 1945. Note the absorption about the lower two screws.

G. Lateral view of the united fracture in April, 1945. Note the sequestrum.



PLATE VII—Case 7: A. A. P. view made in Evacuation Hospital, 14 October, 1944. Note the separation at the joint line.
B. Lateral view made in Evacuation Hospital, 14 October, 1944. Note the rotation of the fractured condyle.
C. A. P. view, 21 March, 1945. The fracture is united with a congruous joint.
D. Lateral view, 21 March, 1945. The fracture is united, with a congruous joint.

Case 7* (see Plate VII)

Indication—Obligate-3: A condylar fracture, with displacement.

Result—"A" The fracture united and the wounds healed, without sequestration or removal of metal.

Diagnosis: Fracture, compound, mildly comminuted medial condyle of left femur.

Wounded: October 14, 1944, missile—not recorded.

Reparative Surgery: On October 24, 1944, the joint congruity was restored by fixation of the displaced condyle with multiple screws through a compound wound. The compound wounds were closed.

Zone of Interior Record: All wounds were healed on admission, and the fracture became solidly united. In March, 1945, knee joint motion was limited to about 15 degrees but plastic surgery upon the quadriceps tendon and the scars is anticipated.

* This patient was managed by Lt. Col. George Duncan.

Case 8 (This patient had fixations of the humerus and ulna)*

Humerus: Indication—Obligate-4: Massive soft-tissue loss.

Result—D: The fracture united and the wounds healed but neither occurred until after removal of metal and sequestra. About six months were required for each, and the union is precarious.

Radius and ulna: Indication—Obligate-2 and 4: Reduction was not achieved by other measures (manipulation) and the displaced fragments projected through a large wound, which also demanded further procedures.

Result—F: The fracture did not unite and the wound did not heal until sequestra and metal were removed.

Diagnosis: 1. Fracture, compound, mildly comminuted right humerus midthird. 2. Fracture, compound, mildly comminuted right radius and ulna upper thirds. 3. Wound of buttocks and lower rectum with colostomy (not here considered).

Wounded: June 2, 1944, by high explosive shell fragments. While he was at the Evacuation Hospital, a diagnosis of gas gangrene was made and appropriate therapy was instituted.

Reparative Surgery: On June 12 he was admitted to the Base Hospital. Between June 16 and 18, three massive hemorrhages from the buttock wound required 6,500 cc. of blood and ligation of the hypogastric artery.

On June 22, the humerus was plated in reduction through the large compounding wound which was partially closed. An effort was made to reduce the radius and ulna and a "hanging-type cast" was applied. Adequate reduction of the forearm was not achieved. When his general condition was satisfactory, on July 22, the ulna was plated in reduction through a septic wound which was partially closed but all bone was not covered. Better drainage of the wound of the arm was established. After a somewhat stormy postoperative course, he was evacuated to the Zone of Interior in late August.

Zone of Interior Record: On admission, September 9, all wounds were draining and the plate on the ulna was visible. On October 7, sequestra and metal were removed from both the humerus and the ulna. Neither was united. At the next change of plaster, in early November, the humerus was stable but during an effort to correct the deformity of the forearm, the humerus was refractured. It reunited, the forearm did not unite, and all wounds healed. The colostomy had not been closed and a fecal sinus through the buttock remained in April, 1945. No illustrations for this case are available.

*No illustration accompanies this case.

SHORTENING OF HUMERUS and REPAIR OF RADIAL NERVE

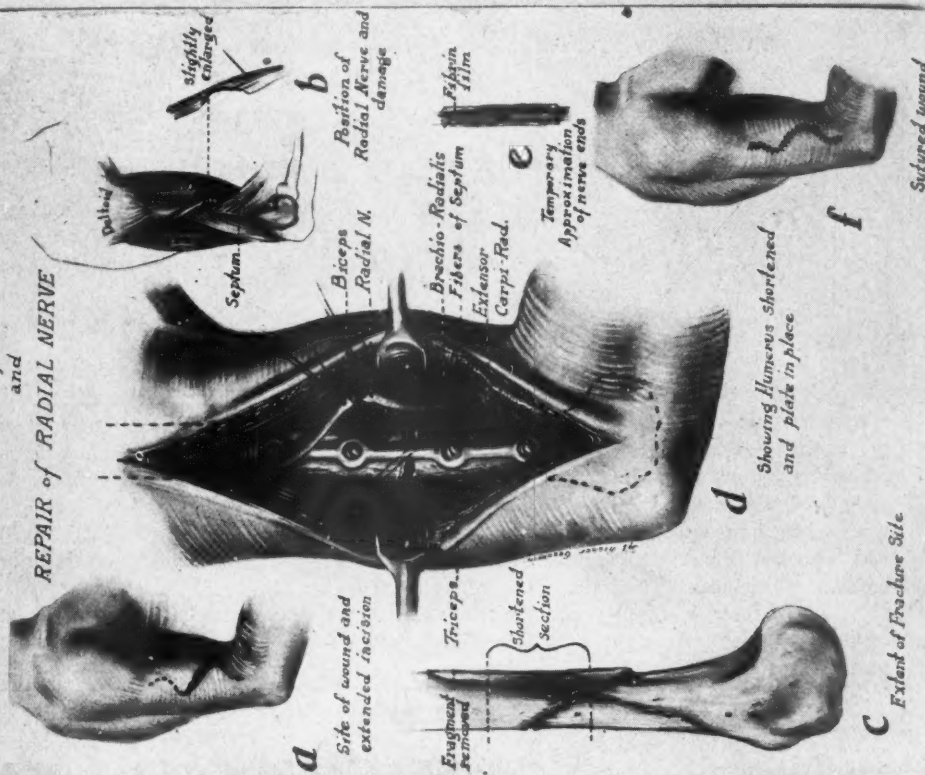


PLATE VIII.—Case 9: A. Artist's drawing of reparative procedure on 6 September.
B. Artist's drawing of the definitive nerve repair.

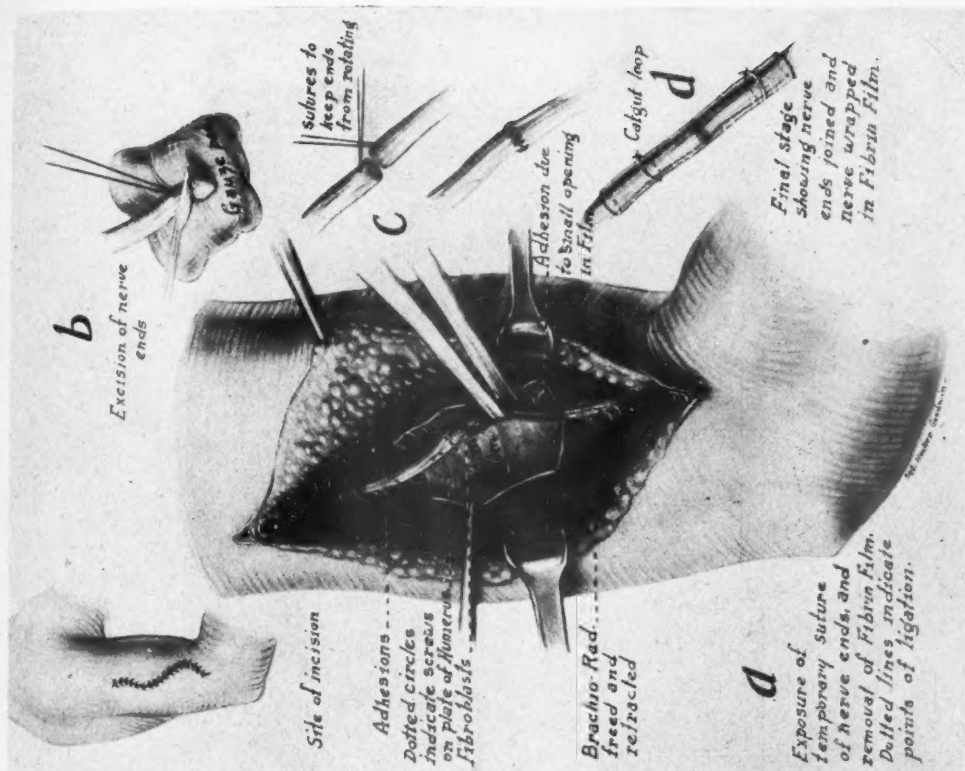


PLATE VIII—(Continued)

C



PLATE VIII (Continued)—C. The united fracture. The wound is healed.

Case 9* (see Plate VIII)

Indication—Obligate-5: Stabilization and, if necessary, bone shortening to facilitate peripheral nerve surgery.

Result—A: The fracture united, and the wounds healed, without sequestration or removal of metal.

Diagnosis: Fracture, compound, comminuted, right humerus with laceration and loss of substance of the radial nerve.

Wounded: August 26, 1944, missile—unknown.

Reparative Surgery: On September 6, at the routine wound visualization of reparative surgery, it was determined that there was loss of about one inch of substance of the radial nerve. The compounding wound was extended. The orthopedic surgeon resected about 1.5 inches of humerus and fixed the fracture in reduction by a four-hole plate plus one transfixion screw. The neurosurgeon approximated the nerve ends and wrapped them in fibrin film. The wound was closed. On September 22, when the wound was healed, a definitive suture of the radial nerve was performed through an operative incision, which healed promptly.

Zone of Interior Record: On admission, all wounds were healed. The fracture went on to solid union. At 5.5 months after repair of the nerve there were definite signs of partial recovery.

* The neurosurgeon was Lt. Col. Henry G. Schwartz, the orthopedic surgeon was Major Joe M. Parker.

PLATE IX

A

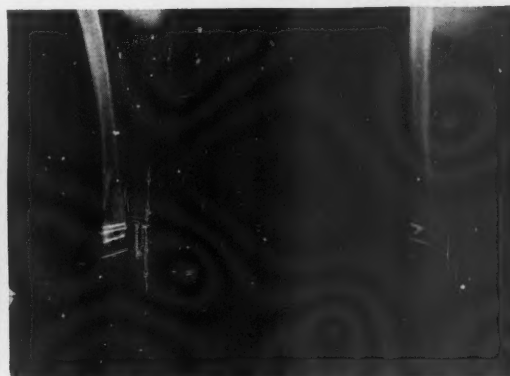
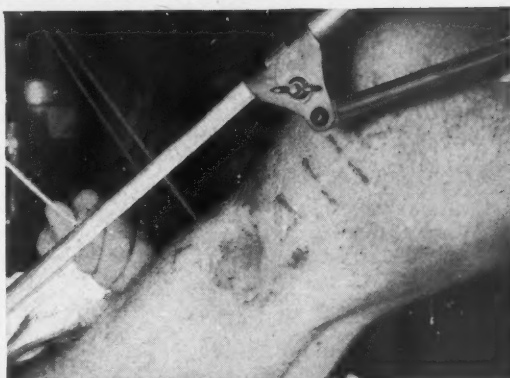
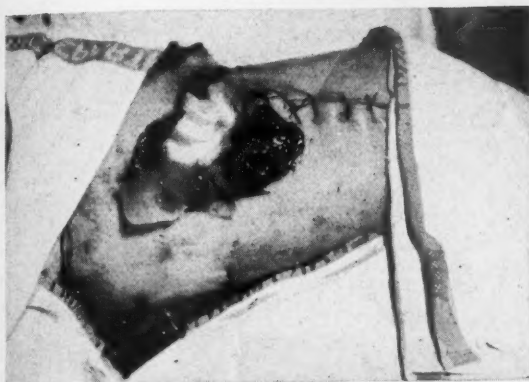


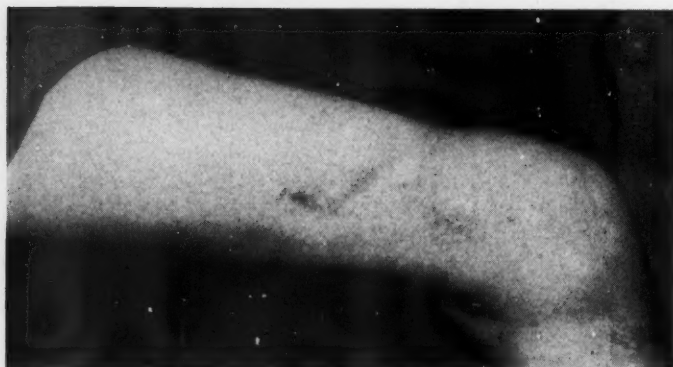
PLATE IX.—Case 10: A. The fixation of the fracture through the compounding wound, with soft-tissue loss extended distally, 9 April, 1944.
B. The partial closure over denuded bone and the dependent drainage, 9 April, 1944.
C. The postoperative roentgenograms, 10 April.
D. The healing wounds in early July.
E. The united fracture in the Z. of I.

Case 10* (see Plate IX)

Indication—Desirable in the femur—a fracture whose contour permits a rigid stabilization by multiple screws or a plate.

Result—A: The fracture united, and the wounds healed, without sequestration or removal of metal.

PLATE IX—(Continued)



F

F. The healed wounds and range of knee motion from extension in March, 1945.

Case 10 (Continued)

Diagnosis: Fracture, compound, complete, bilateral femur, junction mid and lower thirds. (Only the right is considered here.)

Wounded: March 26, 1944, by enemy machine gun bullets.

Reparative Surgery: After adequate blood replacement therapy, on April 9, 1944, exposure of the right thigh revealed a soft-tissue defect of the thigh involving the vastus lateralis and rectus femoris. Through this wound and a distal extension, the femoral fracture was stabilized in reduction by four screws. The wound was partially closed, and dependent drainage was established. The patient was returned to bilateral skeletal traction. During convalescence, he participated in an excellent ward program for the return of knee motion. The soft-tissue defect filled with granulations, and all wounds were about healed when he was evacuated to the Zone of Interior in August.

Zone of Interior Record: On admission, all wounds were healed and the fractures united. When union in each fracture of the femur became sufficiently solid to permit it, weight-bearing in braces was begun. In March, 1945, he was ready for discharge from the army.

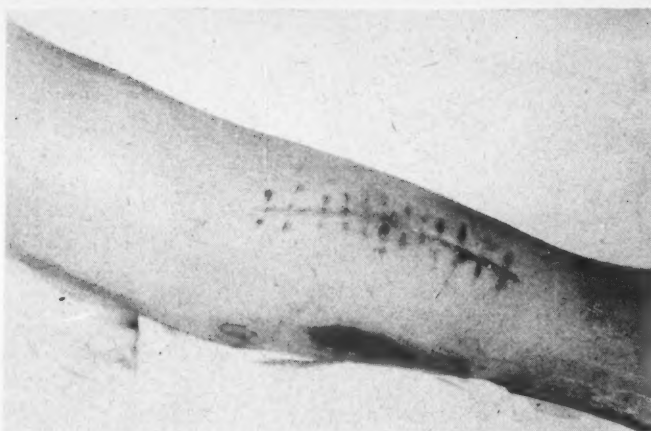
* This patient was managed by Captain John J. Modlin and Major Joe M. Parker.

COMPOUND BATTLE FRACTURES

PLATE X

A

B



C

PLATE X.—Case 11: A. A. P. and lateral views on admission to a Base Hospital.
B. A. P. and lateral views after the fixation, 18 June, 1944. (One screw did not protrude through the opposite cortex.)
C. Healed compounding wound and unhealed relaxation incision (which might have been split-grafted at reparative surgery), 15 July, 1944.

Case 11* (see Plate X)

Indication—Desirable for tibia and fibula—a fracture whose contour permits stable fixation by multiple screws, with minimal periosteal stripping.

Result—A: The fractures united in anatomic alignment, and the wounds healed, without sequestration or removal of metal.

Diagnosis: Fracture, compound, comminuted of left tibia and fibula, midthird.

Wounded: June 8, 1944, by high explosive shell fragments.

Reparative Surgery: On June 17, 1944, removal of the initial encasement revealed

PLATE X.—(Continued)



PLATE X.—(Continued): D. The united fractures, 12 December, 1944. All wounds were healed several months before.
E. The healed anteromedial wounds.
F. The healed posterior wounds.

Case 11 (Continued)

two compounding wounds, one anteromedial, the other posterolateral. Through the former, the oblique fracture of the tibia was stabilized in anatomic reduction by three screws. A posteromedial relaxing incision permitted closure of the anteromedial wound. Drainage was established through the posterolateral compounding wound. The former compounding wounds healed before evacuation to the Zone of Interior.

Zone of Interior Record: On admission, on September 26, 1944, all wounds were healed and the fracture was united. After several months of rehabilitation, he was returned to duty. However, because of some tenderness over the site of a screw head, the screws were removed (one broke) on January 31, 1945.

* This case was managed by Captain John J. Modlin.

COMPOUND BATTLE FRACTURES

Case 12*†

Indication—Desirable in the forearm—any fracture whose contour permits fixation in reduction by internal fixation.

Result—A: The fracture united and the wounds healed, without sequestration or removal of metal.

Diagnosis: 1. Fracture, compound, complete left radius (comminuted with some bone loss) and ulna (transverse), lower thirds. 2. Fracture, compound, comminuted left femur, midthird (not here considered).

Wounded: September 3, 1944, by enemy rifle fire.

Reparative Surgery: On September 11, through compounding wounds, the transverse fracture of the ulna was plated in reduction and a wire loop was used to hold fragments of radius in approximation. The wounds were closed with drainage.

The wounds of the thigh were closed with drainage and skeletal traction was instituted. All wounds healed.

Zone of Interior Record: On admission, October 24, the wounds were healed and the fractures stable. Bony union occurred with synostosis between the bones of the forearm. The metal was prophylactically removed in early April, 1945. No illustrations for this case are available.

* This patient was managed by Major Joe M. Parker and Captain Richard Crouch.

Case 13*†

Indication—Elective in the femur—a nonobligate use of wire loops to hold approximation of fragments.

Result—B: The fracture united in excellent alignment and, after removal of sequestra and metal, the wound healed.

Diagnosis: Fracture, compound, comminuted right femur, midthird.

Wounded: July 1, 1944, missile—not recorded.

Reparative Surgery: July 7, 1944, through the compounding wound, a wire loop was placed so as to obtain contact of major fragments. The wound was closed with drainage. The extremity was returned to balance suspension skeletal traction for ten weeks.

Zone of Interior Record: On admission, October 10, a sinus led to the fracture site. The fracture was united in excellent alignment. On November 22, the wire and sequestra were removed, after which the wound healed promptly. Illustrations for this case are not available.

* This patient was managed by Major Joe M. Parker and Captain John J. Modlin.

† No illustrations accompany these cases.

Case 14* (see Plate XI)

Indication—*Elective in the tibia-fibula*—an elected decision to stabilize a tibia in reduction by plating rather than first attempt reduction by other measures.

Result—B: The fracture united in excellent alignment and, after removal of metal and sequestra, the wound healed.

Diagnosis: 1. Fracture, compound, comminuted right tibia and fibula, lower third.
2. Laceration posterior tibial artery and nerve.

Wounded: March 25, 1944, by high explosive shell fragments.

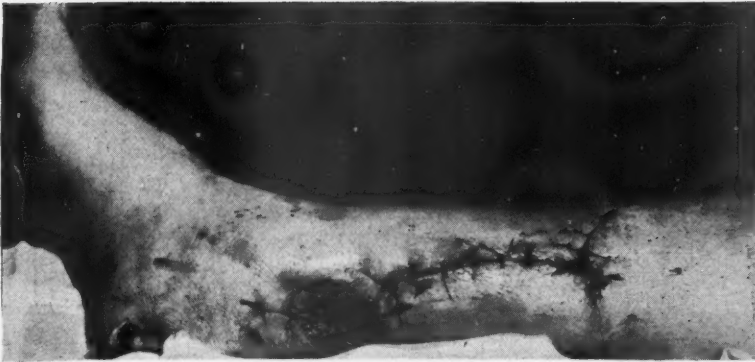
Reparative Surgery: On April 3, 1944, through an extended medial compounding wound, the tibia was plated in reduction. The plate was placed as far posterior as possible. The wound was closed except for an area of loss of skin, which was left open for drainage. A small compounding wound over the fibula was not closed. He was evacuated to the Zone of Interior in early May.

Zone of Interior Record: On admission, all wounds were healed, and the fracture united in normal time. In August, there was some drainage from the medial wound. The metal and several tiny sequestra were removed and the wound was closed, with *per primam* healing. He remains hospitalized because of the residual from the nerve injury.

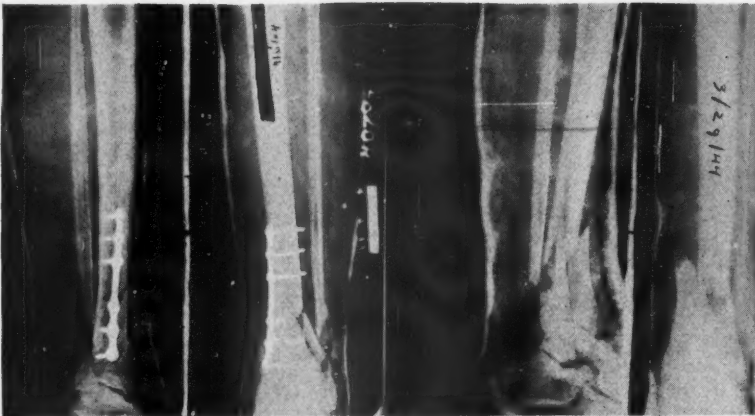
* This case was managed by Major Newton Mead and Captain Richard Crouch.

PLATE XI

A



B



C



D



E

PLATE XI.—Case 14: A. The partially sutured wound following reparative surgery on 3 April, 1945.
 B. The pre- and postoperative roentgenograms—(Note reversal)—Note the loss of bone at site of fracture in the fibula.
 C. A. P. view and rotated A. P. view to show ankle mortise—showing the solid union, in good alignment, 30 March, 1945.
 D. The range of ankle motion in April, 1945.

Case 15* (see Plate XII)

Indication—Elective in the tibia and fibula—Plating of the fibula.

Result—A: The fracture united and the wounds healed, without sequestration or removal of metal.

Diagnosis: Fracture, compound, comminuted right tibia and fibula.

Additional Diagnosis not here Considered: Fracture, compound, comminuted of left humerus, with paralysis of the radial nerve.

Wounded: June 2, 1944, by high explosive shell fragments.

Reparative Surgery: On June 11, 1944, the fibula was plated through compounding wound which was closed with drainage. The compounding wound over the tibia was closed partially.

Zone of Interior Record: On admission, the wounds were healed. The fractures of the tibia and fibula united solidly. Because of some loss of tibial substance, full weight-bearing was delayed.

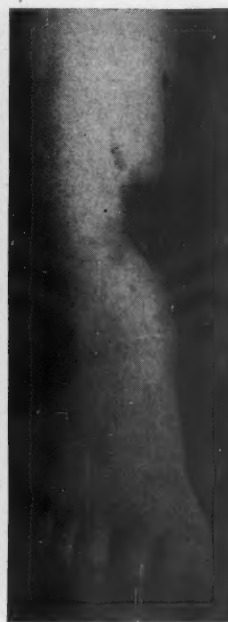
* This patient was managed by Major Herbert W. Harris.

COMPOUND BATTLE FRACTURES

PLATE XII

A

B



C

D

E

PLATE XII.—Case 15: A. A. P. and lateral views on admission to Base Hospital, 9 June, 1944. Note the comminution in the tibia. Fractures in the lower third of the tibia are difficult to reduce.
B. A. P. view on 8 April 1945. The fracture is united in excellent alignment.
C. Lateral view on 8 April, 1945.
D. Frontal view of leg, April, 1945. Note the severe soft-tissue loss.
E. Side view of leg, April, 1945, showing the scar of the fixation wound.

Case 16 (*see Plate XIII*)

Indication—Elective of tibia and fibula—A nonobligate plating, without attempt at reduction by other measures.

Result—B—S: The fracture united but wound healing was not obtained until sequestra, which were massive, and metal were removed.

Diagnosis: 1. Fracture, compound, comminuted, right tibia and fibula. 2. Fracture, compound, comminuted of os calcis, and talus bilateral.

Wounded: July 10, 1944, by a land mine explosion.

Reparative Surgery: On July 16, 1944, the tibia was plated in reduction through the compounding wound, which was closed. Bilateral plaster encasements were applied. The wound over the tibia did not heal. When the plaster for evacuation to the Zone of Interior was applied on August 30, three inches of bare bone were visible.

Zone of Interior Record: All wounds were draining on admission, October 3, 1944. The metal was picked out on the ward on December 17. The fracture was stable, as there was a bridge of bone posteriorly. Later, sequestra were removed and then the wound healed. The bones of the foot are a distorted mass. Amputation might have been considered in all echelons.

PLATE XIII

A

B

C



D

E

F

PLATE XIII.—Case 16: A. A. P. view on admission to Base Hospital.
B. Lateral view on admission to Base Hospital.
C. A. P. view after internal fixation.
D. Lateral view after internal fixation.
E. A. P. view after removal of sequestra and metal. The fracture is united, but note the heavy sequestration reducing the strength of the bone.
F. Lateral view after removal of sequestra and metal. The fracture is united, but note the heavy sequestration reducing the strength of the bone.

Case 17 (see Plate XIV)

Indication—Elective in the tibia and fibula—Internal fixation by plating without a previous effort at reduction by other measures.

Result—F: The fracture did not unite, and the wounds did not heal. There was massive sequestration.

Diagnosis: Fracture, compound, comminuted left tibia and fibula, midthird.

Wounded: September 30, 1944, by high explosive shell fragments.

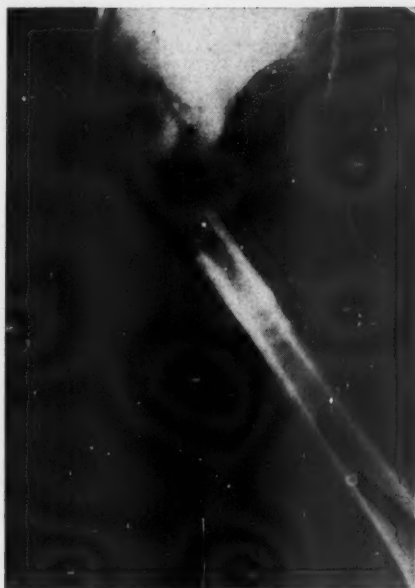
Reparative Surgery: On October 9, 1944, the fracture of the tibia was stabilized in reduction by a long plate and one transfixion screw through the wound, which was closed. Postoperative roentgenograms revealed a more distal fracture, which was not seen on the original films, with some displacement. A few days later this was fixed in reduction by two screws, and the wound again closed. Wound healing was not obtained.

Zone of Interior Record: On admission, January 18, 1945, the wound was gaping, revealing the metallic fixation and dead bone, which were removed. Since that time the wound has improved in appearance but in late March there was minimal drainage, and the fracture was not united.

COMPOUND BATTLE FRACTURES

PLATE XIV

A



B



C



D



PLATE XIV.—Case 17: A. A. P. and lateral views on admission to Base Hospital. B. A. P. and lateral views after internal fixation. C. A. P. and lateral views on admission to Zone of Interior Hospital in January, 1945. D. A. P. and lateral views—1 March, 1945—showing bone defect after removal of massive sequestra and metal.

Case 18*†

Indication—Elective in the humerus—A nonobligate internal fixation, without a previous effort at reduction with other measures.

Result—A: The fracture united in good alignment, without sequestration or removal of metal.

Diagnosis: Fracture, compound, comminuted, humerus.

Wounded: September 20, 1944, by a bullet.

Reparative Surgery: About October 1 three wire loops were placed to hold the fragments in contact through a compounding wound, which was closed. Wound healing followed.

Zone of Interior Record: On admission, December 20, the wounds were healed, and the fracture was united in good alignment. No illustrations for this case are available.

* This patient was managed by Major Irvin Cahen.

† This case not illustrated.

Case 19 (see Plate XV)

Diagnosis: Fracture, compound, oblique left femur midthird.

Wounded: September 17, 1944, by high explosive shell fragments.

Base Hospital Record: On September 26 skeletal traction was instituted and the wound closed with drainage. The wounds healed, and fair apposition and good alignment of the fracture were obtained. After 16 weeks in traction, he was placed in a hip spica for evacuation to the Zone of Interior.

Zone of Interior Record: On admission, there was minimal lateral bowing. Traction was not reinstituted. Further bowing and angulation with a nonunion followed.

Evaluation: This fracture contour would have permitted stabilization in reduction by multiple screws. The results in the series here reported indicate that, by delayed internal fixation, a nonunion might have been obviated.

COMPOUND BATTLE FRACTURES

PLATE XV

A



PLATE XV.—Case 19:
A. A. P. and lateral
while in traction over-
seas.



B. The nonunion in
March, 1945.

B

Case 20 (*see Plate XVI*)

Diagnosis: Fracture, compound, comminuted, left humerus junction mid and lower thirds.

Wounded: January 21, 1944, by high explosive shell fragments.

Base Hospital Record: There was a definite segmental defect from bone loss. The fragments were pushed into approximation and a shoulder spica applied. The bony apposition was fair. The wounds healed, and the patient was evacuated to the Zone of Interior.

Zone of Interior Record: On admission, the wounds were healed, but a nonunion of the fracture was present. Several months later, bone grafting was performed. The extremity remains in plaster, but it is thought that union is occurring.

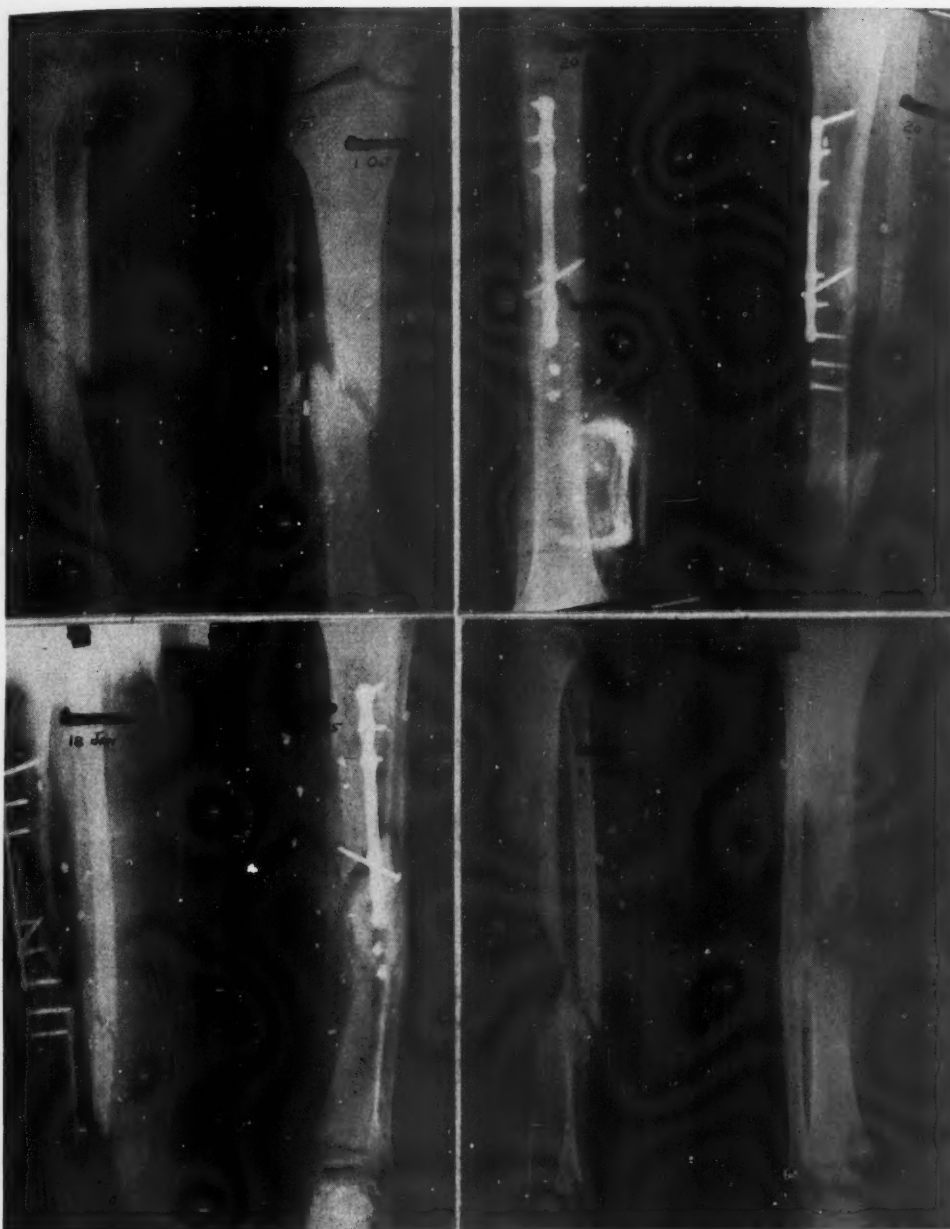
Evaluation: By the judicious use of delayed internal fixation (probably wire) improved bony contact could have been achieved, with enhanced chances of union of the fracture, as is evident in this series. Fifteen months after wounding this upper extremity is still immobilized, with bony union probable but not certain.

COMPOUND BATTLE FRACTURES

PLATE XVI

A

B



C

D

PLATE XVI.—Case 20: A. A. P. view of defect in humerus on admission to Base Hospital.
B. Lateral view of defect in humerus on admission to Base Hospital.
C. The reduction achieved by nonfixation measures. A nonunion followed.

THE SURGICAL SIGNIFICANCE OF THE ACCESSORY SPLEEN

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SPLENECTOMY, for certain diseases involving the formed elements within the blood, is gaining in breadth of application. A better understanding of the functional interrelation of the bone marrow, peripheral blood and spleen has resulted in a sounder basis for surgical therapy. In the development of the background of pathologic physiology of these diseases, as related to splenectomy, the accessory spleen has become recognized as playing a significant rôle in the end-result, particularly in congenital hemolytic icterus and primary thrombocytopenic purpura. If left to remain when once observed, or if overlooked at the time the spleen is removed, a recurrence of either may eventually become manifest. For several years this was assumed, since the histologic structure of the accessories was the same as that of the major spleen. Moreover, the pathologic activity observed supravitaly in the accessory was identical with that of the major spleen.¹

Three types of observations have been made in establishing that the unremoved accessory spleen may eventually cause a recurrence of either congenital hemolytic icterus or primary thrombocytopenic purpura subsequent to splenectomy: First, recurrence associated with an accessory spleen *found but not removed* at the time of splenectomy since its significance was not then recognized; second, recurrences associated with accessory spleens overlooked at the time of splenectomy, but subsequently found at necropsy, after the patient had died of recurrence; and, third, the most convincing of all, relief from a recurrence by the surgical removal of accessory spleens at a second operation. Later, such instances will be described. Perhaps the same reasoning may be eventually applied in primary splenic neutropenia, pansplenic hematocytopenia, or even to some of the other less well-defined variations within the complex Banti's syndrome.

It is the purpose of this paper to present a list of the diseases for which 174 consecutive splenectomies, as well as four explorations for splenic disease, were accomplished (Table I); a tabulation of the location of 131 accessory spleens found in 56 of these patients (Table II); a survey of the pertinent literature and from these basic findings further to analyze the significance of the accessory spleen. Table I indicates that the two diseases for which the accessory spleen *should* be removed to prevent recurrence, namely, congenital hemolytic icterus and primary thrombocytopenic purpura, were also the two most frequent indications. The four exploratories were: one ligation of the splenic artery and three celiotomies during which the spleen was thoroughly examined but not removed. In addition, there was one *accessory splenectomy*

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THE ACCESSORY SPLEEN

for recurrent congenital hemolytic icterus (No. 21, Table I) (No. 7, Table II), subsequent to a previous splenectomy.

THE INCIDENCE OF ACCESSORY SPLEENS

The incidence of accessory spleens has been variously reported by different observers. In the older necropsy reports it ranged around 10 per cent. Adami and Nichols² report an incidence of 11 per cent in their necropsies. Morrison.

TABLE I
THE INDICATIONS FOR SPLENECTOMY OR EXPLORATORY CELIOTOMY

Disease	No. of Operations	Percentage of all Operations
1. Congenital hemolytic icterus.....	53	29.70%
2. Primary thrombocytopenic purpura (including 1 exploratory).....	33	18.50%
3. Banti's syndrome (including 2 exploratories and 1 ligature of the splenic artery).....	33	18.50%
4. Hypoplastic anemia.....	13	7.30%
5. Lymphatic leukemia.....	7	3.93%
6. Pansplenic hematocytopenia.....	6	3.37%
7. Hodgkin's disease.....	5	2.80%
8. Acquired hemolytic icterus.....	4	2.24%
9. Splenic neutropenia.....	4	2.24%
10. Myelogenous leukemia.....	4	2.24%
11. Traumatic rupture of spleen.....	3	1.68%
12. Polycythemia vera.....	2	1.12%
13. Splenic leukopenia.....	2	1.12%
14. Felty's syndrome.....	2	1.12%
15. Lymphosarcoma of the spleen.....	2	1.12%
16. Erythroblastic leukemia.....	1	0.56%
17. Moniliasis of the spleen.....	1	0.56%
18. Luetic splenomegaly.....	1	0.56%
19. Sickle cell anemia.....	1	0.56%
20. Portal cirrhosis with ascites.....	1	0.56%
Total splenectomies (174) and 1 exploratories (4).....	178	
21. Recurrent congenital hemolytic icterus (2 accessories found and removed from one of the above cases).....	1	

Lederer and Fradkin,³ however, after thoroughly searching their necropsy material found an incidence of 35 per cent. They report that Sassuchin found 15 per cent in 153 necropsies of children under age ten. Jolly⁴ observed 25 per cent in 80 children under age 17. Maingot⁵ reported eight instances in a series of 18 splenectomies for essential thrombocytopenic purpura, an incidence of 44.4 per cent. Curtis and White⁶ state that seven (20 per cent) of their first 35 splenectomies revealed accessory spleens. McLaughlin⁷ reported a 24 per cent incidence in a series of 13 splenectomies for congenital hemolytic icterus.

The incidence of accessories found at necropsies with "normal" spleens should be differentiated from that of patients with splenic disease, since there may be an effect of the fundamental pathologic process upon the incidence of accessory splenic tissue. In our series, as listed in Table I, a total of 56 of our 178 consecutive patients presented accessory spleens. Fifty-three instances

were observed during the splenectomy, two at necropsy of previously splenectomized patients, and one at the time of a second operation, planned specifically to search for accessories in a patient with recurrence. This represents a general incidence of 31.4 per cent, as distributed throughout the various splenic disease and age-groups.

ACCESSORY SPLEENS IN THE VARIOUS AGE-GROUPS

Since the splenectomies were performed in relatively equal numbers in the first six decades (except for the third decade, Table III), the age-incidence of accessory spleens may be compared. Thus, Table III reveals that accessory spleens are more common in the earlier age-groups. This general tendency has also been noted in children without splenic disease. However, the 50 per cent incidence in the first decade, as well as the 39.1 per cent in the second, in this series with splenic disease, is considerably higher than reported incidences among "normal" children (15 per cent by Sassuchin and 25 per cent by Jolly). It agrees well with Maingot's⁵ report of 44.4 per cent accessories in a series of 18 patients splenectomized for primary thrombocytopenic purpura.

Inasmuch as the incidence of accessory spleens is considered to decrease with advancing age, we may assume it occurs by some form of involutional atrophy. This ensues by processes similar to those which result in the decreased weight of the normal spleen in the aged and in a gradual percentage decrease of spleen weight from the time of birth onwards, both of which Krumbhaar⁸ regarded as physiologic. Rocher⁹ is said to have observed, at necropsy, many accessory spleens undergoing atrophy in infants. Thus, it may be suggested that an accessory spleen disappears during the normal process of involution unless it is influenced to remain by some intrinsic pathologic process, such as in primary thrombocytopenic purpura or congenital hemolytic icterus. The greater incidence of accessories in individuals with splenic disease over those with "normal" spleens may thus be clarified.

ACCESSORY SPLEENS IN CONGENITAL HEMOLYTIC ICTERUS AND PRIMARY THROMBOCYTOPENIC PURPURA

The greater incidence of accessory spleens in congenital hemolytic icterus (Table IV), compared to a similar age series in primary thrombocytopenic purpura (Table V), might be expected. Owing to its true genetic nature congenital hemolytic icterus may be active, even at the time of birth, when accessories are more numerous. Of the 53 splenectomies for congenital hemolytic icterus, 33 were in the first three decades (Table IV). Fifty-seven point one per cent of the patients in the first decade, and 42.8 per cent in the second presented accessory spleens (Table IV).

Of the 33 operations for primary thrombocytopenic purpura (all splenectomies save one exploratory) (Table V), 23 were during the first three decades. The incidence of accessory spleens, 44 per cent in the first decade and 33.3 per cent in the second, is less than in congenital hemolytic icterus. In but one instance were accessories found beyond the age of 29 in patients with thrombocytopenic purpura (Table II, No. 52).

THE ACCESSORY SPLEEN

TABLE II

56 PATIENTS WITH 131 ACCESSORY SPLEENS FOUND DURING
174 SPLENECTOMIES AND 4 EXPLORATORIES (TABLE I)

No.	Sex	Age	Date of Splenectomy	Disease	Description of Accessories from Operative Record
1.	F	10	4-26-34	Banti's syndrome	A small accessory at the hilus
2.	M	52	11-8-34	Hypoplastic anemia	One accessory, 1.5 cm. in diameter, retro-peritoneal
3.	F	56	2-13-35	Cong. hemolytic icterus	One accessory, 1.5 cm. in diameter, posterior pedicle
4.	F	31	1-2-36	Cong. hemolytic icterus	Eight accessories, the largest 3 cm. in diameter, five about the hilus, three along the splenic vein in the pedicle, the smallest 2 or 3 mm. in diameter
5.	F	45	8-17-36	Banti's syndrome (ligature splenic artery)	Three accessories in the omentum
6.	M	41	5-8-37	Banti's syndrome	One small accessory, 8 mm. in diameter, in the pedicle
7.	F	9	2-22-38	Recurrent cong. hemolytic icterus	Two accessories, retroperitoneal above the tail of pancreas
8.	M	52	2-24-38	Hypoplastic anemia	Two accessories, 1 cm. and 2 cm. in diameter, in the anterior greater omentum
9.	F	68	11-28-39	Pansplenic hematocytopenia	One large accessory, 2 x 2 x 1.5 cm., at the hilus
10.	F	7	3-24-39	Cong. hemolytic icterus	Six accessories, largest 2 cm. in diameter, at the hilus
11.	M	24	4-7-39	Banti's syndrome	One accessory, 2 x 1 x 1.5 cm., at hilus
12.	F	39	6-3-40	Splenic neutropenia	Two accessories, one 1.5 x 1.5 x 1.5 cm., the other 1 x 1 x 1 cm. at pedicle
13.	M	12	6-8-39	Cong. hemolytic icterus	One accessory at lower part of pedicle
14.	F	40	11-4-40	Hodgkin's disease of spleen	One accessory, 1 cm. in diameter, on anterior great omentum just below transverse colon
15.	M	11	4-17-41	Cong. hemolytic icterus	Two small accessories, one at hilus, other within omentum
16.	F	46	4-24-41	Erythroblastic leukemia	One accessory, anterior surface of omentum
17.	M	12	5-13-41	Thrombocytopenic purpura	Three accessories, largest measuring 2 x 1 x 1 cm., all at hilus
18.	F	9 mos.	6-2-41	Cong. hemolytic icterus	Three accessories, largest 1 cm. in diameter, at hilus
19.	M	3	9-4-41	Cong. hemolytic icterus	One accessory, 1.5 cm. in diameter, retro-peritoneal, near inferior pole of spleen
20.	M	48	9-9-41	Pansplenic hematocytopenia	One accessory, 2 cm. diameter, in bowel mesentery
21.	F	12	9-24-41	Thrombocytopenic purpura	Four accessories, all in the pedicle
22.	M	19	10-16-41	Banti's syndrome	Eight accessories, largest 1 cm. in diameter, all at pedicle
23.	M	7	12-1-41	Cong. hemolytic icterus	Four accessories, one in omentum, three at hilus, largest 3 x 2 x 2 cm.
24.	F	28	12-6-41	Cong. hemolytic icterus	One accessory, 2 x 2 x 1 cm., at hilus
25.	F	7.5 wks.	1-22-42	Cong. hemolytic icterus	One accessory at hilus
26.	M	8	2-13-42	Thrombocytopenic purpura	One accessory at hilus
27.	M	58	7-10-42	Banti's syndrome	One accessory, 1.5 cm., in omentum
28.	M	7	10-3-42	Banti's syndrome	Two accessories, in omentum on left side
29.	M	29	11-14-42	Banti's syndrome	One accessory at the hilus
30.	F	62	1-31-43	Cong. hemolytic icterus	One accessory at the hilus
31.	M	15	2-1-43	Banti's syndrome	Ten accessories, four at hilus, and six in the pedicle
32.	F	32	3-18-43	Hodgkin's disease of spleen	Two accessories, one at hilus, other in spleno-colic ligament
33.	F	23	6-19-43	Banti's syndrome	Three accessories at hilus
34.	F	54	8-12-43	Polycythemia vera	Two accessories, one at hilus and one on omentum
35.	M	7	10-28-43	Banti's syndrome	Three accessories, in pedicle
36.	F	5	11-17-43	Thrombocytopenic purpura	One accessory at pedicle
37.	F	26	11-18-43	Thrombocytopenic purpura	One accessory at hilus
38.	M	59	11-20-43	Chronic lymphatic leukemia	Four accessories at hilus
39.	F	25	12-17-43	Lymphosarcoma	Five accessories, largest 2 cm. in diameter, at hilus

TABLE II—(Continued)

56 PATIENTS WITH 131 ACCESSORY SPLEENS FOUND DURING
174 SPLENECTOMIES AND 4 EXPLORATORIES (TABLE I)

No.	Sex	Age	Date of Splenectomy	Disease	Description of Accessories from Operative Record
40.	M	10 mos.	1-2-44	Cong. hemolytic icterus	One accessory at pedicle
41.	F	27	1-12-44	Thrombocytopenic purpura	Two accessories at hilus
42.	F	9	2-24-44	Cong. hemolytic icterus	One accessory, 1.5 cm. in diameter, at hilus
43.	F	28	3-1-44	Cong. hemolytic icterus	One accessory, 3 x 2 x 2 cm., retroperitoneal to left of pedicle
44.	M	32	6-26-44	Hodgkin's disease of spleen	One accessory at hilus
45.	M	12	6-28-44	Cong. hemolytic icterus	Two small accessories, one at hilus, other on anterior omentum
46.	M	4	7-1-44	Thrombocytopenic purpura	One accessory at hilus
47.	M	5	7-8-44	Thrombocytopenic purpura	One accessory at hilus, 2 cm. in diameter
48.	M	22	7-15-44	Banti's syndrome	One accessory, 2 cm. in diameter, retroperitoneal, just lateral to and below the hilus
49.	F	58	7-21-44	Lymphatic leukemia	Five accessories, largest 2.5 cm. in diameter, at hilus
50.	F	22	7-24-44	Luetic splenomegaly	Three accessories, largest 1 cm. in diameter, at hilus
51.	F	71	10-9-44	Splenic neutropenia	Four accessories, largest 1 cm. in diameter, at hilus
52.	M	40	10-24-44	Thrombocytopenic purpura	Two accessories, one ant. and one post. to pedicle
53.	F	56	11-9-44	Cong. hemolytic icterus	Two accessories, one at hilus and one in splenicocolic ligament
54.	M	47	2-26-45	Pansplenic hematocytopenia	Three small accessories at hilus

ACCESSORY SPLEENS FOUND AT NECROPSY OF PREVIOUSLY SPLENECTOMIZED PATIENTS

No.	Sex	Age	Date of Death	Disease	Date of Splenectomy	Description of Accessories
55.	F	21	7-4-44	Thrombocytopenic purpura	9-9-42	Two small accessories, retroperitoneal, at tail of pancreas, 1.5 cm. diameter
56.	M	14	11-11-44	Banti's syndrome	3-9-44	Two accessories in great omentum just below left stomach, 8 mm. diameter

INDIVIDUAL DISTRIBUTION

Only one accessory was found in each of 26 patients (Table II). The remainder, presenting more than one, are also listed in Table VI. Single accessories are more frequent in the younger age-group, likewise, multiple accessories. Thus, the patient with ten accessories is in the second, the patient with six in the first, and the two with eight are in the second and fourth decades, respectively (Table VI). The majority of multiple accessory spleens occur in the young. These findings strengthen the concept that accessory splenic tissue is more frequent during infancy and childhood.

SPLENOSIS AND AUTOTRANSPLANTATION

There is another occurrence of multiple accessory spleens, however, which is apparently different. Thus, Albrecht,¹⁰ in 1896, reported as many as 400 accessories in a single patient, and cited a similar case observed by Orth. Schilling¹¹ presented a patient whose peritoneum contained many small splenotic nodules. These were considered to be accessory spleens. At the present time these highly multiple splenules are not considered in the same category as the usual accessory spleen. Nevertheless, they constitute an

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important variation, bearing a direct relationship to traumatic rupture of the spleen and to the technic of the usual splenectomy.

Moreover, von Kuttner,¹² in 1910, Faltin,¹³ in 1911, von Stubenrauch,¹⁴ in 1912, and again in 1920,¹⁵ Lee,¹⁶ in 1923, Kupperman,¹⁷ in 1936, Shaw and Shafi,¹⁸ in 1937, Jarcho and Anderson,¹⁹ in 1939, and Hamrick and Bush,³⁹ in 1942, reported similar instances of patients with numerous small accessory spleens scattered throughout the peritoneal lining. These had all developed *subsequent to splenectomy for traumatic rupture of the spleen*. These small nodules in most instances contained the characteristic splenic pulp, however, the supporting framework, so characteristic of the spleen, was

TABLE III
AGE INCIDENCE OF SPLENECTOMIES AND EXPLORATORIES (TABLE I) WITH AGE INCIDENCE OF ACCESSORY SPLEENS (TABLE II)

Decade	No. of Cases Operated	No. of Cases with Accessories	Percentage Incidence of Accessories
1-9 yrs.....	28	14	50.0%
10-19 yrs.....	23	9	39.1%
20-29 yrs.....	43	11	25.5%
30-39 yrs.....	25	4	16.0%
40-49 yrs.....	22	7	31.8%
50-59 yrs.....	25	8	32.0%
60-69 yrs.....	11	2	18.1%
70-79 yrs.....	1	1	100.0% (1 case)

TABLE IV
INCIDENCE OF ACCESSORY SPLEENS IN CONGENITAL HEMOLYTIC ICTERUS

Decade	No. of Cases Operated	No. of Cases with Accessories	Percentage Incidence of Accessories
1-9 yrs.....	14	8	57.1%
10-19 yrs.....	7	3	42.8%
20-29 yrs.....	15	2	13.3%
30-39 yrs.....	7	1	14.2%
40-49 yrs.....	2	none	00.0%
50-59 yrs.....	7	2	28.4%
60-69 yrs.....	1	1	100.0% (1 case)

often more or less incomplete. In certain of the nodules the histologic structure was entirely normal. Buchbinder and Lipkoff,²⁰ in 1939, pointed out the similar sequence of events in all of these cases, namely: traumatic rupture of the spleen followed by splenectomy, then, after a variable lapse of time, subsequent inspection of the peritoneum either at operation or at necropsy reveals numerous small splenotic nodules, widespread, and in unusual locations.

Buchbinder and Lipkoff,²⁰ after reviewing the literature, report a similar case with a similar history. In their patient certain of the small accessories were located in the parietal peritoneum, as well as elsewhere along the peritoneal lining. The microscopic picture resembled normal splenic tissue, except for a paucity of lymph follicles and trabeculae as well as the presence of occasional atypically arranged blood vessels. These numerous small accessory spleens were considered as *transplants* resulting from seeding of the peritoneum subsequent to the scattering about of splenic fragments by hemorrhage from

the ruptured spleen. This concept was designated by Buchbinder and Lipkoff as "*splenosis*."

That splenosis resulted from the autotransplantation of splenic tissue was opposed by von Stubenrauch,^{14, 15} who, reporting his case and subsequently another, was the most ardent proponent of the "splenoid" theory, which was at that time generally accepted. Von Stubenrauch reasoned that loss of splenic tissue can be compensated in several ways: by cellular changes in bone marrow and lymph nodes, as well as in preëxisting hemolymph nodes; by regeneration of the main mass of splenic tissue when incompletely removed or by hypertrophy of true accessory spleens; or by formation within the peritoneum of organs having a structure similar to that of splenic tissue which he named "splenoids." These splenoids formed as a sort of replace-

TABLE V
INCIDENCE OF ACCESSORY SPLEENS IN PRIMARY THROMBOPENIC PURPURA

Decade	No. of Cases Operated	No. of Cases with Accessories	Percentage Incidence of Accessories
1-9 yrs.....	9	4	44.0%
10-19 yrs.....	6	2	33.3%
20-29 yrs.....	8	3	37.5%
30-39 yrs.....	3	0	00.0%
40-49 yrs.....	3	1	33.3%
50-59 yrs.....	2	0	00.0%
60-69 yrs.....	2	0	00.0%

TABLE VI
NUMBER OF ACCESSORY SPLEENS PER PATIENT—BY DECADES

Decade	Patients with Acc.	One Acc.	Two Acc.	Three Acc.	Four Acc.	Five Acc.	Six Acc.	Eight Acc.	Ten Acc.
1-9 yrs.....	14	8	2	2	1		1		
10-19 yrs.....	9	2	3	1	1			1	1
20-29 yrs.....	11	6	2	2		1			
30-39 yrs.....	4	1	2					1	
40-49 yrs.....	7	4	1	2					
50-59 yrs.....	8	3	3		1	1			
60-69 yrs.....	2	2							
70-79 yrs.....	1				1				
Totals.....	56	26	13	7	4	2	1	2	1
Total of 131 accessories in 56 patients									

ment for the removed spleen. Kreuter,²¹ however, showed by his research on Rhesus monkeys that total splenectomy did not result in any such compensatory formations. Embryologically, the spleen develops from anlagen in a specific area of the celomic epithelium (left side of the dorsal mesogastrium). Von Stubenrauch carried his idea further by presuming that under exceptional circumstances epithelial anlagen might occur in a number of other foci, thereby giving rise to any number of splenic nodules.

The unusual anatomic locations in which splenotic nodules are found, as well as the circumstances under which they occur, argue convincingly against the "splenoid theory." Finding these nodules on the parietal peritoneum along the line of incision,¹⁸ under the intestinal subserosa,^{12, 18, 16, 20} on the peri-

toneum of the left diaphragm and on the liver surface,^{10, 18, 19, 39} further discounts the theory since the splenic anlagen form on the *left* side of the cephalward portion of the dorsal mesogastrium, which is splanchnic mesoderm. Moreover, the location of nodules found in the lesser omentum and suspensory ligaments of the liver,^{11, 18, 19} which were originally ventral mesogastrium, are further incompatible with the theory.

Splenosis has not been described following splenectomy for nontraumatic disease of the spleen, save in one questionable instance.⁷ This raises further objection to the "splenoid theory." Thus, not removal of the spleen, but rather trauma resulting in seeding of the peritoneum with small splenic fragments, appears to be the important factor in producing splenosis. The questionable case⁷ may as reasonably be considered as splenosis resulting from peritoneal seeding with splenic fragments liberated during the process of a splenectomy. The findings reported are in accord with the mechanism of autotransplantation.

Splenosis subsequent to traumatic rupture of the spleen is but rarely encountered. However, its actual frequency is not known owing to the limited number of celiotomies, or of necropsies, on those abdomens in which splenectomy was previously successfully accomplished for traumatic rupture. Splenosis, according to our present knowledge, is best regarded clinically as an autotransplantation of splenic tissue.

Moreover, it is now well established that autotransplantation of splenic tissue may be readily accomplished experimentally. Even von Stubenrauch¹⁴ successfully implanted autogenous splenic fragments in many and various experimental animals. He also observed that transplanted splenic tissue tends to regress, and consequently discounted the phenomenon of autogenous transplantation. Kreuter²¹ excised the mammalian spleen and smeared its pulp over the peritoneal surfaces. Later, he found widely scattered nodules resembling splenic tissue. Putschar²² went further in placing autogenous splenic implants in subcutaneous tissue, in addition to those on the peritoneum. All but two of Putschar's transplants developed into splenic nodules, even those developing within the subcutaneous tissue, remote from celomic epithelium.

Roettig, Nussbaum and Curtis²³ successfully implanted splenic tissue on the peritoneum (parietal as well as omental and mesenteric) in the rabbit. They observed that splenotic nodules became grossly visible in the rabbit not earlier than six months following the seeding of the peritoneal surfaces. Kupperman's report¹⁷ of a 15-year-old boy developing splenosis within six months after an emergency splenectomy for traumatic rupture, indicates that in man occurs an even more rapid development of splenic tissue transplanted to peritoneum. Putschar,²² and also Perla,²⁴ observed serially in rats that splenic transplants to muscle and subcutaneous tissue fully regenerate within a period of from two to three weeks.

Shaw and Shafi,¹⁸ after studying their patient with splenosis, report an atypical framework within the splenotic nodules. They even found one nodule in the left pleural cavity at the level of the eighth dorsal vertebra and another

just inside the capsule of the left lobe of the liver. It was difficult to explain their presence in these locations save by assuming an unrecognized rent in the diaphragm or a tear in the liver surface, which healed without leaving a visible scar. We have found no instance reported wherein these splenotic nodules, arising after splenectomy for rupture of a normal spleen, subsequently became the seat of primary splenic disease.

SPLENOSIS FOLLOWING THE USUAL SPLENECTOMY

* The mechanism active in the establishment of splenosis thus becomes of clinical significance during a splenectomy for primary splenic disease, since the spleen may be accidentally torn either during manipulation or dislocation or because of capsular adhesions. Resultant fragments may thus fall onto peritoneal surfaces where they implant and thus give rise to splenosis. In a patient with congenital hemolytic icterus it is reasonable to assume that such might result in a recurrence. As reported by McLaughlin,⁷ a patient with congenital hemolytic icterus remained well for two years following splenectomy, and then suffered recurrence. During the succeeding five years she was given 90 blood transfusions. At necropsy, a striking enlargement of all abdominal "hemolymph" nodes, ranging from 1 to 3 cm. in diameter, was observed. No accessory splenic tissue was reported even after careful search.

The now well-established concept of splenosis, with autotransplants spread throughout the peritoneal surfaces, the similarity in structure of the hemolymph nodes as well as their infrequency of occurrence and limited distribution, all give rise to some uncertainty. Perhaps it is more reasonable to regard this case as an example of accidental "seeding" of the peritoneal surfaces with splenic tissue during a difficult splenectomy, rather than as a compensatory enlargement of differing lymph nodes. Following such a concept, we should even be cautioned as to the technic of splenectomy, to avoid tearing of the spleen or after such an injury, against the spilling of splenic tissue out into the peritoneal cavity. Taking note of the successful transplantations of Putschar,²² and Perla,²⁴ into subcutaneous tissue and muscle, we should avoid "contamination" even of the abdominal wound.

SURGICAL LOCATION OF ACCESSORY SPLEENS

To avoid overlooking accessory spleens a routine search should be made, after the major spleen has been removed and hemostasis effected, in the following approximate order: (1) The hilar region; (2) the splenic pedicle; (3) the retroperitoneal region surrounding the tail of the pancreas; (4) the great omentum, and especially along its attachment to the greater curvature of the stomach; (5) the splenocolic ligamentary attachments; (6) the mesentery of both large and small intestines; and (7) in the female, the left adnexa. Because in three out of four²⁴ (36—Table II, No. 7) (Table II, No. 55) proved recurrences, the overlooked accessory spleens were later found in the retroperitoneal region, about the tail of the pancreas, this area should be searched with especial care. Moreover, owing to our present knowledge of splenosis, search should also be made for any fragments torn off because of

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capsular adhesions or clamping too close to the hilus when a short pedicle is encountered. The location incidence of 131 accessories found in the 56 patients is presented in Table VII. This reveals an increasingly greater incidence, a doubling frequency, as one approaches the hilus of the major spleen.

Accessory spleens have also been reported in other regions, as in the tail and body of the pancreas, and even in the scrotum attached to the tunica albuginea of the left testis.^{25, 26, 27} According to the diminishing frequency of

TABLE VII
LOCATION OF 131 ACCESSORY SPLEENS

Location	No. of Accessories	Percentage Incidence
Hilus.....	71 accessories	54.20%
Pedicle.....	33 accessories	25.10%
Omentum.....	16 accessories	12.20%
Retroperitoneal.....	8 accessories	6.10%
Splenocolic ligament.....	2 accessories	1.50%
Bowel mesentery.....	1 accessory	0.75%

accessories as one departs from the major spleen (Table VII), an indicated 3 per cent may possibly be found in the region of the pancreas, a further indication for careful exploration of this region after the splenectomy.

THE DISTRIBUTION OF ACCESSORY SPLEENS

Accessory spleens but rarely occur in two different locations in the same individual (eight times in 178 cases) (Tables II and VIII). Eighty-five point seven per cent of the patients with accessories, varying from one to eight in number, had them in a *single location*. In no instance were accessory spleens found in more than two locations in the same patient (Table VIII). In all eight instances of double location, accessories at the hilus always constituted one (hilus and omentum, four cases; hilus and pedicle, two cases; hilus and splenocolic ligament, two cases—total eight). The location of accessory spleens may be described as *hilar*, *at the pedicle*, or *in the omentum*, rather than in designated splenic ligaments. This appears the more fundamental since it indicates their distance from the major spleen, a significant factor in their development.

In two instances of unusual locations of accessory spleens the pattern of distribution did not vary from that observed in this series. In a patient with Hodgkin's disease with complete *situs inversus*, Rhodes and Grunberg²⁸ found at necropsy nine accessory spleens separately suspended from the greater curvature of the stomach, a single location. Also Olken's case²⁷ presented, in addition to a left scrotal accessory, a second accessory spleen at the hilus.

THE EMBRYOLOGIC BACKGROUND

The occurrence of accessory spleens as well as their various locations, even in the scrotum, can be more clearly understood by considering five phases of splenic embryonic development^{29, 30}: (1) the manner of formation of the

major spleen, with its notches and lobulations, by fusion of separate splenic masses originating on the left side of the dorsal mesogastrium; (2) the formation of accessory spleens by failure of splenic anlagen to fuse; (3) the formation and development of the subjacent dorsal mesogastrium into the various peritoneal ligaments and bursae, carrying along the accessory spleens to their various distant locations; (4) the development of the splenic artery and its branches, providing a similar blood supply to both splenic lobules and accessory spleens³²; and (5) the embryonic contiguity of the splenic anlagen to the genital ridge, permitting an accessory spleen to become attached to the left gonad.^{25, 26, 27}

The splanchnic mesoderm surrounds the entodermal gut tube, forming a dorsal mesogastrium which suspends the embryonic gut from the midesophagus to the cloaca. Dorsal to the stomach the mesothelium and subjacent cells on the left side of the dorsal mesogastrium differentiate to form several splenic anlagen. Microscopically, the splenic anlagen appear as areas of varying size and differentiation. By subsequent fusion of many of these splenic aggregates, a single organ is eventually formed. One or more of these small splenic "hillocks" may not form close enough to the main group, or early enough to fuse with them, and, thus, an accessory spleen may be formed. The notches and lobules of the major spleen appear to originate as a result of partial or incomplete fusion of separate splenic masses.³²

Whether failure or fusion occurs cephalad, ventrad, or caudad from the major masses, and whether this occurs early or later in embryonic development, appears to determine the eventual location of the accessory spleen. If failure of fusion occurs immediately ventrad, relatively late in development, hilar accessories presumably will occur. If the same splenic mass fails to fuse earlier, the subjacent growing dorsal mesogastrium will displace it from the hilus, presumably to become a pedicle accessory spleen. The same phenomenon underlies omental accessories when one takes into consideration that the great omentum began as part of the mesogastrium immediately dorsal to the greater curvature of the stomach.

Accessories within the intestinal mesentery result from an early failure of fusion of an anlage caudad to the aggregate splenic mass. An accessory in the splenocolic ligament arises from a splenic anlage in that part of the primitive mesentery of the colon that does not fuse with the parietal peritoneum but which becomes fused to the peritoneum of the splenic pedicle. No accessories have been found in the head of the pancreas, which originates as a ventral budding of the gut entoderm. However, accessories do occur about the body and tail, which is surrounded by the dorsal mesogastrium from which the splenic anlagen arise.

Retroperitoneal accessories become thus situated because they are within those portions of dorsal mesentery which fuse to the posterior parietal peritoneum, such as the mesentery of the colon and the mesentery dorsal to the pancreas. Paul³¹ reports the instance of two retroperitoneal accessory spleens just lateral to the peritoneal attachments of the ascending colon on the right

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TABLE VIII
NUMBER OF ACCESSORY SPLEENS IN EACH LOCATION PER PATIENT

Case No.	Acc. at Hilus	Acc. at Pedicle	Acc. in Omentum	Accessories Retroperitoneal	Acc. in Spleno-colic Lig.	Acc. in Bowel Mesentery
1.....	1			1		
2.....		1				
3.....		3				
4*.....	5		3			
5.....		1				
6.....				2		
7.....			2			
8.....						
9.....	1					
10.....	6					
11.....	1					
12.....		2				
13.....		1				
14.....			1			
15*.....	1		1			
16.....						
17.....	3					
18.....	3			1		
19.....						1
20.....		4				
21.....		8				
22.....			1			
23*.....	3					
24.....	1					
25.....	1					
26.....	1					
27.....			1			
28.....			2			
29.....	1					
30.....	1					
31*.....	4	6			1	
32*.....	1					
33.....	3					
34*.....	1		1			
35.....		3				
36.....		1				
37.....	1					
38.....	4					
39.....	5					
40.....		1				
41.....	2					
42.....	1					
43.....				1		
44.....	1					
45*.....	1		1			
46.....	1					
47.....	1					
48.....				1		
49.....	5					
50.....	3					
51.....	4					
52.....		2				
53*.....	1					1
54.....	3					
55.....			2			
56.....				2		

* Patients presenting accessory spleens in two different locations.

side. This right-sided location is presumably the result of rotation and elongation of the developing colon together with its suspending mesentery. Mediastinal accessory spleens presumably may occur¹⁸ as a result of embryonic factors, since the dorsal mesogastrium originally extends into the mediastinum, suspending the esophagus. They result by failure of fusion of a cephalad splenic mass.

An accessory spleen attached to the tunica albuginea of the left testis or to the mesovarium of the left ovary may be traced to the original close proximity of the mesonephros with its medially placed genital ridge, to the embryonic spleen. A splenic mass, contiguous to the genital ridge, may attach itself to the gonadal anlage and later actually descend into the left scrotum or pelvis.

Variations in the anatomic pattern of the splenic artery, and of the associated morphology,³² also indicate that the spleen develops from multiple anlagen. Ssosan-Jaroschewitsch described two types of splenic artery: (1) The "magistral" type, which is a long single artery dividing near the hilus into two or three terminal branches; and (2) the "distributed" type, in which a short artery divides into eight to 12 branches relatively far from the spleen. Furthermore, the "distributed" splenic artery was usually associated with a greatly lobulated and unevenly contoured spleen, whereas the "magistral" was usually associated with a spleen of relatively smooth contour. Michels³² pointed out that the tubercles and lobules of the spleen were supplied by separate arterial twigs which arose from splenic artery branches, and that areas separated by incisurae also had separate arterial supplies. A developmental history of multiple splenic anlagen, each with its own arterial twig, accounts for such a separate blood supply.

Michels incidentally describes a few instances of accessory spleens, found in the gastrosplenic and splenocolic ligaments, which received their blood supply from the inferior polar branches of the splenic artery. The accessory spleen, supplied by a branch of one of the splenic artery terminals, which also supplies a major spleen lobule, furnished further evidence that its origin was as one of the aggregate masses intended to form part of the spleen early in development, but having failed to fuse, carried with it its original blood supply. Thus, the accessory spleen represents a greater degree of fusion-failure when compared to cleft and lobule formation of the major spleen.

The origin of an accessory spleen, found attached to the tunica albuginea of the left testis is vividly indicated in Olken's case.²⁷ A continuous narrow bridge of splenic tissue extended from the scrotal accessory up through the inguinal canal and internal inguinal ring to connect with the posterior inferior aspect of the major spleen, which occupied its normal position. Sneath's case²⁵ is similar, except for a gap in the splenic bridge in the lower abdomen. The splenic tissue tapers to a thin cord below the spleen, and continues as a thin strand of peritoneum to the scrotal accessory. The case reported by Emmett and Dreyfuss²⁶ did not present the connecting link of splenic tissue, but in its place was a fibrous band.

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In the embryo the contiguity of the left genital ridge, lying along the medial side of the mesonephros, to the developing spleen permits a splenic anlage to become attached to the mesentery of the embryonic gonad. The developmental descent of the gonad with its mesentery thereupon carries the attached spleen into the left pelvis in the female or into the left scrotal sac. Judging from Sneath's and Olken's cases, separation of the gonadal accessory spleen from the major spleen may be incomplete, and from Emmett and Dreyfuss' case, complete.

ACCESSORY SPLEENS CAUSE RECURRENCE

Morrison, Lederer and Fradkin³ originally called attention to accessory splenic tissue as a probable cause of recurrence following splenectomy for primary thrombocytopenic purpura. They reported two cases for which splenectomy was successfully accomplished, yet only one fully recovered. At the time of splenectomy in the case that did not recover, an accessory spleen was observed but not removed, because its significance was then not fully appreciated.

Curtis and White⁶ regarded the unremoved accessory spleen as the cause of recurrence following splenectomy for congenital hemolytic icterus or for primary thrombocytopenic purpura. They refer to hemolymph nodes as possibly capable of either continuing or acquiring hemolytic properties in excess of normal and thereby contributing to the recurrence of congenital hemolytic icterus. Vaughn,³³ in a review of the treatment of primary thrombocytopenic purpura, stated that relapse occurring subsequent to a period of satisfactory recovery after the splenectomy was probably due to the development of a spleniculus. Moreover, he tabulated a 17 per cent recurrence of primary thrombocytopenic purpura following splenectomy in 303 cases collected from the literature. Watson and Moir³⁴ suggest that the 11 per cent incidence of accessory spleens found by pathologists (Adami and Nichols²), compares closely enough with the 17 per cent incidence of recurrence to explain its cause.

Watson and Moir³⁴ reported primary thrombocytopenic purpura in a woman of 43 for whom splenectomy was accomplished and following which she was practically well for six years, although occasionally mild symptoms were noted. Recurrence of the severe hemorrhagic tendency finally caused the patient's death. At necropsy, an accessory spleen was found one centimeter above the tail of the pancreas, and measured 2.8 cm. in diameter. This weighed 12 Gm., and was verified microscopically. Sufficient megakaryocytes were noted in the bone marrow. The idea that accessory spleens might be the cause of the recurrence was advanced even before the patient's death but was not seriously considered.

McLaughlin, Sharpe, and Cunningham,³⁵ in discussing the results of splenectomy for familial hemolytic jaundice, reported 13 cases. They advanced the opinion that when sufficient evidence of hemolysis reappears, subsequent to splenectomy, it may be assumed either that (1) the original

diagnosis was incorrect; or (2) that overlooked splenic tissue had become active; or (3) that hemolymph nodes had hypertrophied and assumed excessive hemolytic activity. McLaughlin⁷ cites an instance, previously referred to under splenosis, of congenital hemolytic icterus remaining well for a period of about two years subsequent to splenectomy. At the end of this interval the patient developed profound anemia because of recurrence. At necropsy a striking enlargement of the "abdominal hemolymph nodes," ranging from 1 to 3 cm. in diameter, was observed. No accessory splenic tissue was found by the pathologist, in spite of a careful search. This latter report is not entirely clear to us. Hemolymph tissue is not frequent in the human abdomen. Moreover, its distribution is limited. There might even arise some question as to its identity and histologic differentiation. The evidence, both clinical and experimental of autotransplantation as the cause of splenosis, as well as the fact that hemolymph tissue may resemble the atypical splenotic structures, would favor this case as one of recurrence due to the development of splenosis from "seeding" of the peritoneum at the time of splenectomy.

OUR OWN TWO RECURRENCES

Two pertinent cases indicating that accessory spleens, if left behind at the time of splenectomy, can cause recurrence of the primary splenic disease (congenital hemolytic icterus or primary thrombocytopenic purpura) for which the spleen was originally removed, occurred in this series of 174 consecutive splenectomies.

The first, referred to by Dr. Charles A. Doan,³⁶ in 1940, is as follows:

CASE REPORTS

Case 1.—G. P., female, age 4.5 years, entered the University Hospital, September 12, 1933, appearing pale and listless. She had always been somewhat anemic. Three months previously she began experiencing sudden episodes of listlessness. One month previously she suffered a similar attack with which was associated definite icterus. Her family history later revealed the familial tendency to hemolytic jaundice.

Physical examination revealed normal development. The child was extremely ill, lethargic, poorly nourished, and presented a definite icteric tint to the skin. The spleen was enlarged, extending 4 cm. below the costal margin, with a palpable notch along its medial border. No petechiae were observed. Sclerae were not jaundiced. Small cervical and axillary lymph nodes were palpable. Lungs were clear. Heart was negative except for an hemic systolic murmur heard at the apex, and a rate of 120. Blood pressure was 86/36. Nail beds were cyanotic. The icterus was not of obstructive origin. Erythrocyte count was 600,000 per cu. mm., hemoglobin level too low to be read, and there were nearly 100 per cent reticulocytes.

Oxygen was liberally administered, also two small intraperitoneal blood transfusions, during the next few days while observing the patient and arriving at a diagnosis. The temperature varied from 99° to 101.8° F. The jaundice was deepening. A diagnosis of congenital hemolytic icterus was made. An emergency splenectomy was performed September 16, 1933, by Dr. V. A. Dodd. The erythrocyte count immediately rose from 1,020,000 to 2,070,000 postoperatively. Two hundred cubic centimeters of citrated whole blood was infused into the peritoneal cavity before closing the abdomen. Supravital studies of the freshly removed spleen, made by Dr. Charles A. Doan, revealed the "pathognomonic picture of hemolytic icterus, engorgement of R. B. C. in 4-5 phagocytic clasmatoocytes per oil immersion field. No P. M. N., monocytes, or epithelial cells."

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Convalescence was stormy because of gastric atony and dilatation, that responded slowly to treatment, also, because of a transitory obstructive jaundice with clay-colored stools lasting three to four days and followed by spontaneous clearing. Patient left the hospital on October 19, 1933, her 32nd postoperative day, feeling fine, eating well, and with an erythrocyte level at 3,230,000 per cu. mm. Recovery was apparently complete.

Four years and four months later, the child, now nine years old, was readmitted, February 21, 1938, to the University Hospital. In the interim she had been periodically observed by Dr. Charles A. Doan, who found no recurrence of her disease until one month previously. At that time, January 21, 1938, definite hemolysis was observed, associated with return of the original symptoms. In the month preceding this second hospital admission, the erythrocyte count had fallen to 2,409,000, with the hemoglobin at 70 per cent, while the reticulocytes had risen to 39 per cent. A leukocyte count of 10,350, with an approximately normal differential for a nine-year-old child, and a platelet count of 1,727,000 were noted. After clinical study it was decided that the patient presented a recurrence of the hemolytic anemia. Therefore, it was deemed advisable to explore the abdomen and search for the accessory splenic tissue suspected of causing the recurrence. Accordingly, February 22, 1938, the abdomen was reopened by Dr. V. A. Dodd through a left paramedian incision. Two small accessory spleens were discovered in the retro-peritoneal tissue, over the tail of the pancreas, and were removed. In addition, biopsies of the liver and of the enlarged lymph nodes present in the mesentery and in the retro-peritoneal region, were taken.

Supravital studies of the accessory spleens by Dr. Charles A. Doan showed many highly phagocytic clasmotocytes engorged with red blood cells and engulfed pigment. The lymph node and liver sections revealed no excess of phagocytic elements.

Following the accessory splenectomy the patient made a gradual and persistent recovery, with subsequent rise of the circulating erythrocytes and fall of the reticulocytes. This patient, observed for two years afterwards, remained completely free from any evidence of recurrence of the congenital hemolytic icterus.

Thus, is presented a case of congenital hemolytic icterus that recurred subsequent to splenectomy. The recurrence was regarded as due to accessory splenic tissue not removed previously, the patient was explored, accessory spleens were found, removed, and the patient, thereupon, again recovered and remains symptom-free.

Certain questions may be raised, nevertheless, concerning the true nature of congenital hemolytic icterus. With two accessory spleens remaining, why was recovery apparently complete, and later, what was the pathogenesis of the reprecipitation of the disease? The second case report may be originally presented as follows:

Case 2.—V. M., female, age 21, was admitted to the University Hospital, September 4, 1942, a primipara seven months pregnant. She complained of bruising upon slight injury, bleeding gums, and intermittent fatigue of four months duration, starting during her third month of gestation. Petechiae and later ecchymoses appeared, first on the expanding abdomen and later upon the arms. Hematuria was noted three times during a 24-hour period during the third month of pregnancy. Epistaxis occurred occasionally. Three weeks prior to admission she vomited dark red blood, and was hospitalized for several days. Her past history and system review were otherwise essentially negative.

Physical examination revealed a well-developed, well-nourished young woman, age 21, lying quietly in bed. The enlarged abdomen of seven months pregnancy presented numerous petechiae and ecchymoses in addition to those over the extremities and back. The nose was bilaterally congested, with some bleeding from the right nostril. The pale oral mucosa showed evidence of recent bleeding. Tonsils were of moderate size. Mod-

erate lymphoid hyperplasia was present on the posterior pharyngeal wall. One right anterior cervical lymph node was slightly enlarged as was also one of the left supraclavicular group. Breasts were normal for the pregnancy. Chest was clear. The uterine fundus extended two fingersbreadth above the umbilicus. The fetal heart rate was 150. Reflexes were physiologic.

Laboratory data on admission showed a peripheral blood count of 9,050 leukocytes; 3,280,000 erythrocytes; and 6,519 platelets per cu. mm. The differential, by supravital technic, was P. M. N. 70 per cent, P. M. B. 2 per cent, small lymphocytes 4 per cent, intermediate lymphocytes 4 per cent, monocytes 4 per cent, and reticulocytes 7.8 per cent. The hemoglobin was 9.9 Gm. per cent (Newcomer). Three days later no platelets could be found in the peripheral blood. Supravital bone marrow studies showed adequate megakaryocytes with a fairly normal differential, revealing some left shift of both red and white cell elements, consistent with pregnancy. Urinalysis was negative. Serology was negative. Prothrombin time was 115 per cent, blood urea nitrogen 11.0 mg. per cent, blood sugar 78.4 mg. per cent, and blood chloride 564 mg. per cent. The feces showed blood, chemically and microscopically.

The patient was carefully investigated, and a diagnosis of primary thrombocytopenic purpura was made by Dr. Bruce K. Wiseman, who referred the patient for splenectomy. Preparation consisted of daily blood transfusions, two ampules of thyloquinone daily, and daily intramuscular corpus luteum extract, for a preoperative period of three days.

On September 9, 1942, under cyclopropane-oxygen with supplemental ether anesthesia, the abdomen was opened through a left rectus incision. The uterus, with its fundus high above the umbilical level, appeared quite characteristic. Fetal movements were discernible. The wound oozed considerable capillary blood. The characteristic small, purplish, apparently "normal" spleen of thrombocytopenic purpura was found moderately posterior in position, and attached by a short pedicle. Owing to technical difficulties resulting from the large pregnant uterus added to those encountered in a splenectomy of this type, the splenic pedicle was isolated, surrounded by the finger and thumb of the left hand and then clamped blindly. Due care was taken to exclude the stomach and tail of the pancreas. A second clamp was then applied, between the first and the hilus. The spleen was then luxated forward and removed by cutting between the two clamps. Hemostasis was secured by silk ligatures. An exploration for accessory spleens was then made, but none were found. Closure in layers was then accomplished using interrupted silk throughout. The patient left the operating room in excellent condition.

The pathologist, Dr. Harry L. Reinhart, reported the histologic picture as "compatible with thrombocytopenic purpura." There was a moderate hyperplasia of the reticulo-endothelial system, a decrease in the amount of lymphoid tissue, and considerable congestion.

Postoperative course was uneventful except for abdominal distention on the third postoperative day. This was relieved by continuous gastric suction. A fever, ranging preoperatively from 99.0° to 99.4° F. reached its peak, 100.8° F., on the day of operation, returning completely to normal range by the 11th postoperative day. There was no disturbance of the water or mineral balance or of kidney function. No evidence of increased uterine motility was manifest at any time. The patient steadily improved.

The postoperative hematologic recovery during her hospital stay consisted of the characteristic rise in peripheral platelets, from a preoperative range between zero and 12,520 per cu. mm. to an immediate postoperative rise within a few hours to 39,600 per cu. mm. This was followed by a gradual increase to 306,000 by the fifth postoperative day and subsequently to between 627,000 and 793,000 per cu. mm. during the last few days before dismissal. Peripheral erythrocytes varied from 3,280,000 on admission to 3,410,000 at the time of dismissal. Reticulocytes were 7.8 per cent on admission and 6.4 per cent on dismissal. Leukocytes showed no significant variation. A few days before dismissal an indirect van den Bergh was 1.1 mg. per cent, and the direct van den Bergh was delayed three minutes. The icteric index was 20. Clinically, the patient became

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stronger and showed no further tendency to bleed. Her wound healed well. She was dismissed on the 19th postoperative day. Two months later she delivered at full term a normal baby girl. Both parturition and puerperium were quite normal.

Nearly two years later the patient, now 23 years old, was admitted, July 1, 1944, to the service of Dr. T. A. Spitler at the Findlay Hospital. She had been apparently quite normal since splenectomy, until a few days before this admission. She became tired and weak, and noted gingival and vaginal bleeding, together with epistaxis. Her pulse was regular and around 114, temperature 101° F., respirations 30, erythrocyte count 4,070,000, with 70 per cent hemoglobin; leukocytes 15,000, with 89 per cent neutrophils, 64 of which were nonsegmented, 11 per cent lymphocytes and 1 per cent myelocytes. The urine was brownish-red and loaded with red blood cells.

The next day she vomited dark red blood frequently, and was given 2,000 cc. of fluids intravenously. Temperature rose to 104° F., pulse to 126, and her respirations ranged in the thirties. A blood culture, taken after the patient began chilling, later proved negative. On July 3rd, numerous tarry, semiliquid stools were passed, and several chills occurred. She was then bleeding severely, the erythrocyte count by evening had fallen to 1,420,000, with 20 per cent hemoglobin. The leukocytes remained unchanged. The temperature decreased to 101.2° F., and the pulse became thready. Early the next morning, July 4th, the patient expired.

Necropsy was performed by Dr. T. A. Spitler. The stomach was distended, containing more than a quart of bloody fluid. The gastric mucosa presented myriad petechiae and several points of active bleeding. No ulcer was found. Liver was normal in size and shape. The spleen and appendix were both absent. There were hemorrhagic areas on the descending colon and along the small intestine. Two small nodular masses were found retroperitoneally, attached near the tail of the pancreas. These resembled accessory spleens, and consequently were sent to us, together with the other tissues, for further study and microscopic examination.

The pathologist to the University Hospital, Dr. Harry L. Reinhart, reported as follows: V. M., Autopsy No. 35983. *Gross.* The specimen consists of portions of ribs, the tail of the pancreas with two small accessory spleens attached, three lymph nodes, a portion of the liver and a portion of the kidney. Lymph nodes were slightly enlarged, measuring approximately 1 cm. in diameter. The accessory spleens are about 1.5 cm. in diameter. Other tissues are not remarkable.

Microscopic.—Spleen: Moderate enlargement of the accessory spleens, due largely to sinuses packed with monocytes and clasmatoocytes containing phagocytized pigment and other debris. Malpighian bodies present, also lacked protein and fibrinoid deposit. Lymph Node: Marked edema of lymphoid tissue, great dilatation of sinuses. Sinuses contain clasmatoocytes and monocytes actively engaged in phagocytosis of pigment, red cells, white blood cells and debris. Bone Marrow: Slightly hypoplastic. Large number of giant cells both mononuclear of the megakaryocytic type, and polynuclear of the osteoblastic type. There is also evidence of clasmatocytic activity. Kidney: There is diffuse distribution of leukocytes around the tubules. Most of these appear eosinophilic. The cause is not apparent. Liver: Periportal collections of leukocytes and marked phagocytosis of blood pigment by the Kupffer's cells. Pancreas: No noteworthy pathology.

Thus, is presented the second instance of proved recurrence subsequent to this series of 174 splenectomies. Two accessory spleens were found at necropsy. Again, it appears that accessory spleens, if left behind, may cause eventual recurrence of primary thrombocytopenic purpura. To the reports of the infrequency of primary thrombocytopenic purpura occurring during pregnancy and the relative rarity of successful splenectomy during pregnancy for this disease,³⁷ this case may be added. Recurrence of symptoms subsequent to splenectomy occurred later during a pregnancy in several reported cases

and then disappeared after parturition. No direct observations of accessory splenic tissue could be made in these instances because of the vaginal route deliveries and the spontaneous postpartum recoveries from the thrombocytopenic purpura. The important facts of our case are the onset of the disease during pregnancy and the maintained recovery subsequent to splenectomy. Other reports have indicated recurrence of symptoms postsplenectomy, with a spontaneous recovery at its termination. The fact that recurrence did not appear in our patient during the remainder of the pregnancy in the known presence of accessory spleens suggests that there is no causal relationship in pregnancy upon the activation of primary thrombocytopenic purpura.

ACUTE INFARCTION OF THE ACCESSORY SPLEEN

Accessory spleens may become the seat of acute disease bearing no direct relation to the major spleen. Thus, torsion of the pedicle by which the accessory spleen is attached soon leads to severe circulatory disturbance and eventually necrosis. Settle³⁸ reports two such cases, both in children, four and eight years old.

ABBREVIATED CASE REPORTS (SETTLE)³⁸

Case 1.—A four-year-old male child presented severe abdominal pain with a distended, tympanitic and somewhat rigid abdomen. The point of greatest tenderness was in the left upper quadrant. Peristaltic waves were inaudible. The acute pain had been present for three days, with nausea and vomiting. Twenty-four hours after onset, chills, fever, and dehydration complicated the picture. Past history revealed that the child had occasionally cried out with abdominal pain during the two previous years. Temperature was 102.4° F., pulse 120, leukocytes 21,000, with 92 per cent P. M. N.

Upon opening the peritoneal cavity through a left rectus incision, eight hours after admission, 300 cc. of cloudy straw-colored fluid was found. Several loops of small bowel covered with fibrin, as well as the colon, were adherent to an orange-sized mass in the left upper quadrant. Kinking had produced obstruction of the small bowel. After dissecting away the loops of adherent bowel, an encapsulated tumor was found attached by a two-inch pedicle to the gastrosplenic ligament. The mass was quite soft, covered with fresh fibrin and its pedicle was in a state of advanced torsion. The mass was removed, and the major spleen observed to be normal in size, shape and position. Microscopic diagnosis revealed complete infarction of an accessory spleen.

Case 2.—This patient was an eight-year-old female child, with a less acute course. Epigastric pain with tenderness, greatest over left upper quadrant was noted. Localized moderate rigidity was present in this area. An indistinctly movable, tender, lemon-sized mass was palpable in the left upper quadrant. Leukocyte count was 13,000. At operation, an accessory spleen, with its pedicle in torsion and arising from the gastrocolic ligament, was found and removed.

Both patients made uneventful recoveries. Thus, an accessory spleen attached by a pedicle, which becomes twisted, may become hyperemic and infarcted, and cause an "acute abdomen," even with intestinal obstruction. The age-incidence in these two patients bears out the greater frequency of accessories in children.

SUMMARY

The end-result of splenectomy for congenital hemolytic icterus or primary thrombocytopenic purpura is influenced by whether accessory spleens which

may be present are found and removed. This was suggested in 1928 by Morrison, Lederer, and Fradkin for primary thrombocytopenic purpura. Subsequent observations, particularly of accessory spleens found in recurrences after splenectomy, have aided in establishing this conclusion.

The basic data upon which this report is made is presented as a list of the diseases for which 174 consecutive splenectomies and four abdominal explorations were done, and in tables showing the location of the 131 accessory spleens found in 56 of these patients. Further analyses are made. Significantly, the two most frequent indications for splenectomy, congenital hemolytic icterus and primary thrombocytopenic purpura, are the two diseases in which the accessory spleen, if present, must be removed along with the major spleen to prevent recurrence.

The incidence of accessory spleens reported by different observers is as follows:

- 11 per cent of all their necropsy material, by Adami and Nichols.
- 15 per cent of necropsies in children under age ten, by Sassuchin.
- 20 per cent in their first 35 splenectomies, by Curtis and White.
- 24 per cent in 13 splenectomies for congenital hemolytic icterus, by McLaughlin.
- 25 per cent of necropsies in children under age 17, by Jolly.
- 35 per cent of their necropsy material, by Morrison, Lederer, and Fradkin.
- 44 per cent in 18 splenectomies for essential thrombocytopenic purpura, by Maingot.

A greater incidence among the young has been generally noted.

In this series of 178 consecutive patients operated upon for various splenic diseases, 56, or 31.4 per cent, presented accessory spleens. The 50 per cent incidence in the first decade as well as the 39.1 per cent in the second decade is even greater than the increased incidence of accessories ordinarily found in the young with "normal" spleens. The decreasing incidence with advancing age is presumed to occur normally by gradual involution and atrophy. The onset of a pathologic process in splenic tissue apparently causes the accessory to remain and thus occurs the increased frequency of accessories in those with certain splenic diseases.

The greatest incidence of accessories was 57.1 per cent in the first decade in congenital hemolytic icterus. Forty-two point eight per cent were found in the second decade. In primary thrombocytopenic purpura 44 per cent were found in the first decade, and 33.3 per cent in the second decade. Save for the third decade, the incidence of accessories in congenital hemolytic icterus is greater than in primary thrombocytopenic purpura.

The number of accessories per patient varied from one to ten, 26 patients presenting but on accessory spleen. Single as well as multiple accessories occurred predominantly in the young.

The presence of splenules in great numbers, scattered throughout the peritoneum, appears to be a different clinical entity than true accessory spleens. Their occurrence is now known as *splenosis* (Buchbinder and Lipkoff). They

are to be differentiated because (1) they originate by transplantation of fragments of splenic tissue, usually scattered about the peritoneum by hemorrhage from a ruptured spleen; (2) they usually occur in great numbers, reportedly varying from 42 to 400; and (3) they are diffusely distributed throughout the peritoneum, even in areas where splenic tissue does not developmentally arise, as on the parietal peritoneum and ventral mesogastric layers.

The occurrence of splenosis is closely related to the technic of the usual splenectomy, since loose bits of traumatized splenic tissue may accidentally fall onto the peritoneal surfaces and become implanted. Such implants may develop and even result in the original splenic disease. Such may even prove to be the interpretation of one recurrence of congenital hemolytic icterus reported as due to compensatory hypertrophy of hemolymph nodes subsequent to splenectomy. Moreover, since splenic substance may even transplant to subcutaneous tissues, the incision should be protected during splenectomy in the event that the spleen is traumatized.

To avoid overlooking accessory spleens a routine search is made, after the major spleen has been removed, in the following approximate order: (1) Hilar region; (2) splenic pedicle; (3) retroperitoneal region surrounding the tail of the pancreas; (4) the great omentum and especially along its attachment to the greater curvature; (5) colic ligamentary attachments; (6) mesentery of both large and small intestines; and (7) in the female, the left adnexa.

In the 56 patients the 131 accessories were distributed in these locations according to the following percentages: Hilar, 54.2 per cent; pedicle, 25.1 per cent; omentum, 12.2 per cent; retroperitoneum, 6.1 per cent; splenocolic ligament, 1.5 per cent; and bowel mesentery, 0.75 per cent. In 85.7 per cent of the patients the accessories were found in but a single location. In no instance were accessories found in more than two locations in the same patient. In all instances of double location, the hilus constituted one location.

The embryologic background of accessory spleens, as well as their various locations, may be more clearly understood by considering five phases of splenic embryonic development: (1) The manner of formation of the major spleen, with its notches and lobulations, from separate splenic masses originating on the left side of the dorsal mesogastrium; (2) the formation of an accessory spleen by failure of fusion of splenic anlagen; (3) the formation and development of the subjacent dorsal mesogastrium into the various peritoneal ligaments and bursae, carrying along the accessory spleens to their various distant locations; (4) the development of the splenic artery and its branches, with similar distribution to both splenic lobules and accessory spleens; and (5) the embryonic contiguity of the splenic anlagen to the genital ridge, thus, permitting an accessory spleen to become attached to the left gonad and to descend with it into the pelvis or scrotum.

Four instances of recurrence subsequent to splenectomy are presented. In all, accessory spleens were found and appeared to be the cause. Two cases from the literature are briefly summarized. They are the original observations of Morrison, Lederer, and Fradkin, and of Watson and Moir, both

patients having primary thrombocytopenic purpura. The two recurrences thus far observed in our series of 174 consecutive splenectomies are reported in detail, one with primary thrombocytopenic purpura and the other a striking case in which recurrence of congenital hemolytic icterus was relieved by removal of two accessory spleens at a second operation.

Finally, pedunculated accessory spleens may cause acute abdominal symptoms from infarction due to pedicle torsion. This is shown in a summary of two such case reports.

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BILIARY ASCARIASIS

REPORT OF 19 CASES

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ASCARIASIS is one of the most common, if not the most common, helminthic infestation of man. In Szechuan, Chang and Ch'in¹ found 90 per cent of seven different rural population groups infested. In the Philippines various groups range from 40 per cent to 83 per cent infested.⁵ It is widespread in many tropical, subtropical, and even temperate zones. Accordingly, ascariasis, as such, has received considerable attention. Yet its very commonness has led to a certain attitude of benign tolerance and even indifference on the part of the medical profession. It is all too rarely realized that ascariasis is a dangerous disease. Even in comprehensive works on tropical disease its dangers are not emphasized. For example, reference to biliary ascariides, by Stitt and Strong,² is limited to the following: "They may penetrate into any accessible passage or space and cause bizarre and sometimes serious local disturbances; *e.g.*, into the appendix, bile ducts, gallbladder, pancreatic duct, nose, sinuses, middle ear and larynx. . . . Rajahram has reported the case of a girl of six who died with five ascaris-containing abscesses in her liver." Manson-Bahr³ dismisses biliary ascariides with: "They have been known to enter the bile ducts and give rise to jaundice and abscess of the liver."

That ascariides can invade many diverse organs and areas of the body, giving rise to many diverse and at times fatal conditions, is attested by isolated reports which can be found in the literature. A survey of the Quarterly Index Medicus from 1930 to 1943, inclusive, reveals 30 articles on the subject of biliary ascariasis from all parts of the world. All but Crowell's⁵ report concern only isolated instances of one or two cases.

Muir⁶ reported a Chinese case of an ascaride in the common bile duct and gallbladder. He quotes Aviles as having collected 90 cases of ascariasis of the common duct from the literature up to 1918. A more comprehensive report on the dangers of ascariasis was made by Crowell⁵ in 1920. He states "migration of the ascaris into the common bile duct and thence into the gallbladder or into the intrahepatic bile ducts is a frequent occurrence, and must be much more frequent than is indicated by the reported cases, as the diagnosis is made only at operation or at autopsy." He reports 12 autopsy cases of ascariasis of the bile ducts and liver, six of them associated with liver abscess and two with pancreatic duct obstruction and pancreatitis. These cases were observed in the Philippines.

In 1928, Morton⁸ found eight reports of ascariasis of the gallbladder and

reported one case from Virginia. He emphasized two features: First, an history of ascariasis; and second, biliary tract disease.

In 1933, Ch'in⁷ reported a case of acute hemorrhagic pancreatitis due to *ascaris lumbricoides* impaction in the ampulla of Vater, and listed 28 references to biliary or pancreatic ascariasis. In 1936, he reported a case in which ascariasis of the liver caused fatal hemorrhage both into the biliary tract and thence into the gastro-intestinal tract, and directly into the free peritoneal cavity.

Three cases of biliary ascariasis were reported from Szechuan by Chen,⁴ in 1943. Two of these were autopsy cases, one presenting purulent cholangitis with liver abscess, the other showing fossilization of ascarides in the liver. The third case was a clinical case which we report here in further detail as Case No. 1.

The present communication deals with 19 cases of biliary ascariasis observed in the United Hospitals of Chengtu during the past three years. Twelve of the 19 cases have been seen in the past 18 months, suggesting perhaps that as the condition is more carefully sought for it may prove to be even more common than herein indicated.

CASE MATERIAL

Table I provides a brief abstract of 14 of our cases. All but one were under 28 years of age. All but two were Szechuanese, and those two had lived in Szechuan for over two years. Four were males, ten female. All complained of rather severe epigastric and/or right upper quadrant pain except one (No. 9) who had severe epigastric and left upper quadrant pain. As more of these cases were seen we came to feel that there might be a characteristic distending type of pain present in contrast to the stabbing, knife-like pain of cholelithiasis. One patient (No. 8) even stated that he thought something was crawling around inside him. All but three complained of vomiting. The symptomatology in general suggested cholecystitis. Five were jaundiced, although those seen early in their illness tended not to be jaundiced. Epigastric and right upper quadrant tenderness and spasm were common, although the one (No. 9) who had left upper quadrant pain also had left upper quadrant tenderness. The temperatures tended to be low, especially in the cases seen during the first day or two of illness. All but Cases 9 and 12 had stools positive for *ascaris* ova. Eleven had a past history of ascariasis. Ten had had previous similar attacks. All underwent operation, four with the correct preoperative diagnosis, and three with biliary ascariasis as a suggested possibility. The remainder were diagnosed cholecystitis and/or cholelithiasis, except for one case diagnosed liver abscess. Three had acute cholecystitis. Four had distended gallbladders. Five had tense, firm common ducts with a typical catheter-like consistency. Through the wall of the tense duct the white ascaride could be visualized as a light streak. In these cases aspiration yielded only a few drops of bile, if any, and even on incising the common duct no bile escaped in several instances. Six had

BILIARY ASCARIASIS

dilated common ducts, and in the rest the operative descriptions were inadequate. All had ascarides in the common duct. Typically, about one-third of a 20-cm. ascaride projected into one of the hepatic ducts from the site of choledochotomy, while the remaining two-thirds of the ascaride, the caudal two-thirds, extended down the common duct into the duodenum. In Cases 5, 7, and 14 ascarides were also partly, or completely, in the gallbladder. All had choledochotomy except in the liver abscess case, who had incision and drainage only, and Case 5 in whom the worm was manually expressed out of the common duct during celiotomy. Seven choledochotomies were used as choledochostomies by T-tube drainage, while choledochotomies were primarily closed without drainage in four instances. In Case 2 an additional ascaride crawled out alongside the T-tube on the tenth postoperative day. In Case 8 a ring-like impression was noted at about the junction of the middle and caudal thirds of the ascaride suggesting the impress of a spastic sphincter of Oddi. In Case 2 the doubling-up of the worm in a dilated common duct, with head and tail in the lower duct, suggests that at times the worm may enter and leave the duct spontaneously. Two deaths occurred, one due to pericholecystic abscess, peritonitis, and *Friedländer bacillus* septicemia; another due to multiple liver abscesses. All other patients were treated with anthelmintics as soon after operation as their conditions permitted.

COMMENT: The predilection for ascarides to enter any available aperture is well known. At times they have been found projecting through holes in glass beads or buttons inadvertently swallowed. In other instances the appendix may harbor the worm. Crowell⁵ reports a case in which an ascaride burrowed between two adjacent tuberculous intestinal ulcers.

When apertures are not available the adult worm may burrow through tissues to the free peritoneal cavity, into the urinary bladder, or elsewhere. In one local case a deep thigh abscess harbored an ascaride, while in another instance an orbital abscess contained an ascaride.

In this report attention is called to the relative frequency of ascarides in the bile ducts and gallbladder, and to the serious consequences which ensue. It is urged that the disease be regarded with greater respect, and that its dangerous potentialities be recognized. Patients known to harbor the parasite should be vigorously treated before complications develop. Where infestation is widespread, mass therapy is indicated.

In such areas the condition should be suspected in patients presenting symptoms of cholecystitis or common duct obstruction. In these cases adequate preoperative preparation followed by surgical intervention is indicated. Such cases also would seem to be further justification for early surgical treatment as opposed to conservative therapy.

SUMMARY AND CONCLUSIONS

Nineteen cases of biliary tract ascariasis are presented and discussed,

together with excerpts from the literature, to lend support to the contention that ascariasis is a dangerous disease.

If in an endemic area a young person below the usual age for cholelithiasis presents symptoms and signs of biliary tract disease, biliary ascariasis should be suspected. If, in addition, the stool is positive for ascaris ova; there is a recent past history of ascariasis; the patient has recently vomited ascarides; there is an history of previous similar attacks; and the pain has a peculiar distending quality—then the diagnosis of biliary ascariasis can be made with reasonable certainty.

Since the submission of this article for publication, five more instances of biliary ascariasis have been operated upon, and may be added to the 14 summarized in Table I.

FIVE ADDITIONAL CASE REPORTS

Case 15.—Hosp. No. 5012—1945: A 35-year-old Szechuanese woman complained of right upper quadrant and epigastric pain of colicky nature for 18 hours preceding admission. Vomited undigested food several hours after onset of pain, but no ascarides. Past history of vomiting ascarides two years before, but no previous similar attacks. Acutely ill, writhing with pain. No jaundice. Epigastric and right upper quadrant pain and tenderness, with spasm. Temperature 100.4° F.; W. B. C. 12,000. Stool positive for ascaris ova. *Preoperative Diagnosis:* Biliary ascariasis.

Operative Findings: G. B. hugely distended, thickened, neck bound down by adhesions to omentum and duodenum. C. D. dilated to 1.5 cm., not thickened, but two cord-like ascarides palpable in C. D. Two adult ascarides removed through choledochotomy incision, one worm being doubled upon itself. Cholecystectomy and choledochostomy. Uneventful recovery.

Case 16.—Hosp. No. 5193—1945: A 40-year-old Szechuanese woman complained of epigastric pain, severe and colicky, for four days preceding admission. Vomited undigested food, but no ascarides, the day of admission. Past history of vomiting ascarides several years previously, and repeated similar attacks of epigastric pain for 20 years. Acutely ill, doubled-up with pain. No jaundice. Epigastric and right upper quadrant tenderness and spasm. Temperature 99.4° F.; W. B. C. 4,700. Stool positive for ascaris ova. *Preoperative Diagnosis:* Chronic cholecystitis, with cholelithiasis. Suspected biliary ascariasis.

Operative Findings: Greatly dilated G. B., measuring 12 x 13 x 7 cm. Wall somewhat thickened. No stones palpable. C. D., 1 cm. in diameter, not thickened. An ascaride was seen wriggling within the C. D. It was also palpated. Another was palpated in the duodenum. The C. D. was opened and the ascaride previously seen and palpated had disappeared. After some investigation it was found high in the hepatic ducts and withdrawn. It measured 19 x 0.3 cm. During this period the patient vomited a 28-cm. ascaride, after which the duodenal ascaride was no longer palpable. Cholecystectomy and choledochotomy. Death on fourth postoperative day—clinically due to bilateral pneumonia. Autopsy permission refused.

Case 17.—Hosp. No. 5509—1945: The patient was a 40-year-old Szechuanese woman, complaining of severe colicky epigastric and right upper quadrant pain radiating to the right scapula, for four days. N and V present, but no ascarides vomited. No jaundice. Had repeated similar attacks for 20 years, with jaundice. Had ascarides in stool within past six months. Acutely ill, doubled up with pain. No jaundice. Direct tenderness epigastrium and r. u. q., no rebound tenderness, gallbladder questionably palpable, Murphy's sign positive. Moderate r. u. s. spasm. Temperature 99° F.; W. B. C.

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Case No.	Hosp. No.	Age	Sex	Province	Onset of Illness	First Symptoms	Other Symptoms	History of Ascariasis	Other History
1	15429 '42	18	M	Szechuan	12 hours	Severe epigastric pain; n & v	Paroxysmal colicky pain radiating to the r.u.q.	Vomited ascariides 4 yrs. prev.	3 similar prev. attacks
2	18593 '43	19	F	Szechuan	26 hours	Severe epigastric pain; n & v	Paroxysmal colic, sweating and dizziness	Passed ascariides repeatedly	1 similar attack 3 mos. prev.
3	18938 '44	18	M	Szechuan	19 days	Fever and chilly sensations	Severe epigastric and r.u.q. pain, n & v, 5 days	Not recorded	Recurrent abd. pain since age 6
4	2840 '44	23	F	Szechuan	4 hours	Severe epigastric and r.u.q. colic	Radiation to rt. back; n & v	Passed ascariides several months previously	Neg.
5	19178 '44	46	F	Szechuan	3 days	Severe r.u.q. colic	Vomited 20 ascariides; chilliness and fever	Vomited ascariides many times in past	Many similar prev. attacks, with jaundice
6	19839 '44	26	M	Szechuan	4 days	Fever and headache	Severe epigastric and r.u.q. pain 20 hours	Ascariides passed in childhood	One similar prev. attack
7	20128 '44	15	F	Szechuan	40 days	Epigastric pain; vomited ascariides	Subsidence after 6 days; recurrence 10 days prev. to adm.	Neg.	Occ. prev. attack
8	4095 '44	22	M	Hunan; 2 yrs. in Szechuan	2 days	Severe epigastric and r.u.q. pain	Vomiting; fever	Passed ascariides in recent years	Neg.
9	4600 '45	19	F	Hupai; 6 yrs. in Szechuan	20 hours	Chill followed by fever	Severe epigastric and l.u.q. pain, vomiting, 1 hour	Neg.	Neg.
10	4696 '45	24	F	Szechuan	10 days	Nausea and vomiting of ascariide	Epigastric and r.u.q. pain, 5 days	Passed and vomited ascariides many times prev.	Many similar prev. attacks
11	4794 '45	13	F	Szechuan	1 day	Severe epigastric pain	Vomiting 6 hrs.	Passed and vomited ascariides many times	Many similar prev. attacks
12	21939 '45	23	F	Szechuan	2 mos.	Acute epigastric colic; chills, fever; productive cough	Severe vomiting 2 mos. Distension, edema. Epigastric mass	Repeatedly passed ascariides	Occ. prev. attacks
13	22240 '45	11	F	Szechuan	3 days	Epigastric and r.u.q. colic	Vomited 20 ascariides	Repeatedly vomited ascariides	Occ. prev. attacks
14	22324 '45	27	F	Szechuan	8 hours	Severe r.u.q. colic radiating to rt. back	Chilliness and headache for 5 days	Passed ascariides repeatedly	Neg.

ABSTRACT OF CASES OF BILIARY ASCARIASIS

Other History	Other Physical Signs	Preoper. Temp., Fahr.	W.B.C.	Ascaris Ova in Stools	Preoper. Diag.	Operative Findings	Operation	Course
Similar attack prev.	Acutely ill; epigastric and r.u.q. tenderness and spasm	97.4-98.6	10,000	++	Cholelithiasis	Congested and distended G.B.; C.D. tense and firm; 20-cm. ascaride removed, cephalad one third above, caudad two thirds below incision	Cholecystectomy; choledochostomy	Uneventful recovery
Similar attack prev.	Slightly ill; epigastric and r.u.q. tenderness and spasm; Murphy's sign positive	98-100	12,000-21,000	++	Acute cholecystitis with cholelithiasis	Distended noncompressible G.B.; C.D. distended; large ascaride doubled up in C.D., head and tail toward duodenum	Cholecystectomy; choledochostomy	Adult ascaride crawled out along T-tube 10th p.o. day; recovery
ent abd. + ence age 6	Dehydrated, acutely ill; moderate epigastric tenderness and spasm	101	13,500-10,000	++	Cholecystitis	Acute phlegmonous cholecystitis with gen. peritonitis; pericholecystic abscess; C.D. dilated and contained one ascaride	Ditto, + drainage cholecystic abscess	Friedländer bacillus septicemia; death
	Acutely ill; tenderness and rigidity r.u.q.; Murphy's sign positive	95.6-99	15,000	+	Acute cholecystitis with ? biliary ascariasis	G.B. mod. dilated; C.D. tense and catheter-like; ascaride visible through C.D. wall; 27-cm. female ascaride removed	Cholecystectomy; choledochotomy	Ext. biliary fistula 4 mos.; recovery
Similar attacks, and ice	Acutely ill; tenderness and spasm r.u.q.	98-98.2	7,000-10,000	+++	Cholecystitis	Acute cholecystitis; cholangitis; 4 ascarides in G.B., 2 in C.D.	Cholecystectomy; choledochostomy	Mild p.o. atelectasis; recovery
Similar prev.	Acutely ill; r.u.q. tenderness and spasm	101-102	14,700-19,000	++	Cholecystitis with cholelithiasis	G.B. normal; ascaride palpated in stomach, duodenum, and C.D., removed by manual expression	Expl. celiotomy; manual expression ascaride	Mild p.o. atelectasis; recovery
v. attack	Acutely ill; tenderness and spasm r.u.q. with egg-sized mass	102	23,000	+++	Cholecystitis	G.B. normal; C.D. dilated; 7 ascarides removed from C.D. including 1 which extended into G.B.	Choledochostomy	Uneventful recovery
	Acutely ill; tenderness and spasm r.u.q.; Murphy's sign positive	100.2	14,000-21,000	+	Biliary ascariasis	G.B. acutely inflamed and distended; C.D. tense, firm, 8 mm. in diam., catheter-like; no bile from choledochotomy; 25 x 0.5 cm. female asc. removed	Cholecystectomy; choledochotomy	Transient p.o. jaundice; recovery
	Acutely ill; cyanotic; drowsy; epigastric and l.u.q. and bilat. C.V.A. tenderness	95-100	15,000	0	Acute pancreatitis? biliary ascariasis?	G.B. normal; C.D. tense, firm, 8 mm. in diam., catheter-like; no bile on incision; ascaride visible through wall, removed, 20 cm. long	Choledochotomy	Intestinal obstruction 14th day due p.o. adhesions; lysis, rec'y
Similar attacks	Acutely ill; epigastric and r.u.q. tenderness and spasm; Murphy's sign positive	97.4-103	13,000	+	Biliary ascariasis	G.B. sl. distended; C.D. distended to 1.5 cm.; ascaride palpable in C.D.; 20 cm. long on removal, upper two thirds in hepatic duct	Choledochostomy	Mild p.o. atelectasis; recovery
Similar attacks	Acutely ill; epigastric and r.u.q. tenderness and spasm	99	15,000	++	Biliary ascariasis	G.B. distended, not inflamed, non-compressible; C.D. tense, catheter-like; 10-cm. ascaride removed	Choledochotomy	Uneventful recovery
	Acutely and chronically ill; 3+ distended; pus discharging from epigastric sinus; r.u.q. and an epig. tenderness	99-102	11,000-22,000	0	Liver abscess? due to ascariasis	Incision into spontaneous sinus tract and ruptured liver abscess; autopsy: multiple liver abscesses, ascariasis of hepatic ducts, intra-hepatic calculosis	Incision and drainage	Death
	Md. ill; epigastric and r.u.q. tenderness; distended; L & S 4 cm. below costal margin	99-100.2	13,000-25,000	+	Biliary ascariasis	B.G. slightly congested, compressible; C.D. sl. dilated; 2 ascarides palpable and removed through choledochotomy	Choledochotomy; cholecystostomy	Uneventful recovery
	Md. ill; r.u.q. spasm and tenderness; 4 x 5-cm mass in r.u.q.; Murphy's sign positive	98	14,000-16,000	++	Acute cholecystitis with cholelithiasis	G.B. distended; C.D. dilated to 1.8 cm.; ascaride felt in G.B. and C.D.; on removal 30 cm. long, with cephalad one third in G.B.	Cholecystectomy; choledochostomy	Uneventful recovery

9,000. Stool 1+ for ascaris ova. *Preoperative Diagnosis:* Cholelithiasis, with chronic cholecystitis and hydrops of gallbladder. Suspected biliary ascariasis. *Operative Findings:* G. B. greatly dilated 15 x 9 cm., not acutely inflamed. C. D. dilated, 2 cm., not thickened. Ascaride palpable in upper C. D., on choledochotomy, found doubled up with both ends extending into hepatic ducts, central portion just above choledochotomy incision. On removal measured 26 x 0.5 cm. Also some cystic and C. D. sand. *Operation:* Cholecystectomy and choledochostomy. Uneventful recovery.

Case 18.—Hosp. No. 23167—1945: The patient was a 14-year-old Szechuanese boy, complaining of severe colicky epigastric and right upper quadrant pain of eight hours duration. N and V present, patient vomited three times, but no ascarides were noted. No jaundice. Had repeated similar previous attacks for two years. No ascarides had been passed previously. Moderately ill. Direct tenderness in epigastrium and r. u. q., with positive Murphy's sign. Temperature 100° F.; W. B. C. 10,450. Stool 2+ for ascaris ova. *Preoperative Diagnosis:* Biliary ascariasis. *Operative Findings:* G. B. normal. C. D. 1 cm. in diameter, and containing an adult ascaride, about 20 cm. in length. *Operation:* Choledochostomy. Uneventful recovery.

Case 19.—Hosp. No. 5600—1945: A 26-year-old Szechuanese male entered complaining of severe epigastric pain, cramp-like and colicky, of 16 hours duration. Vomited eight times, but no ascarides noted. No jaundice. Similar attacks in childhood. Ascariasis in childhood. Moderately ill, occasionally doubling-up with severe pain. Right epigastrium tender. Liver edge descends 1.5 cm. on inspiration, and is tender. No rebound tenderness or spasm. Temperature 98.6°–100° F. Stool negative for ova. W. B. C. 10,700. *Preoperative Diagnosis:* Suspected biliary ascariasis. Observed and rehydrated for 18 hours, during which time there was no improvement in symptoms. *Preoperative Diagnosis:* Biliary ascariasis. *Operative Findings:* G. B. moderately dilated to 10 x 6 cm. G. B. wall somewhat thickened. C. D. normal in appearance, about 1.0 cm. in diameter; but an ascaride was palpable and faintly visible therein. On removing the ascaride, the head was found projecting into the hepatic ducts, the tail down toward the sphincter of Oddi. The ascaride measured 20.5 x 0.3 cm. *Operation:* Choledochotomy, cholecystectomy. Uneventful convalescence.

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SYMPATHECTOMY FOR ISCHEMIA FOLLOWING FEMORAL ARTERY LIGATION

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IN VIEW of the current interest and lack of agreement in the value of sympathectomy following ligation of the femoral artery, the following five cases are reported. The cases are similar in that all had the superficial femoral artery and vein ligated between the profunda femoris branch and Hunter's canal. The first case was observed for three months then sent to limited duty without sympathectomy. In three cases sympathectomy was performed after a two months observation period. The fifth case had a sympathectomy immediately following the ligation of the vessels.

Dr. I. A. Bigger, in a recent article,¹ points out the frequency of permanent reduction of blood supply to tissues, especially the muscles, following interruption of large arteries. He reports seven out of eight cases with interruption of the main artery of the lower extremity (iliac to popliteal) had definite symptoms of chronic circulatory deficiency distal to the obstruction on examination after a period of nine months to eight years. One case which did not have these symptoms had had an injection of the lumbar sympathetic ganglia with alcohol.

CASE REPORTS

Case 1.—A 24-year-old Ordnance Sergeant was wounded in action, March 16, 1944, at 0700 hours, at Anzio Beachhead in Italy, sustaining a penetrating wound of the left thigh from enemy shell fragments. The fragment divided the femoral artery and vein at the proximal end of Hunter's canal. He received 1 cc. of tetanus-toxoid and sedation at the Battalion Aid Station and was then sent to an Evacuation Hospital. At 1000 hours, March 16, 1944, three hours after injury, the wound was débrided and the femoral artery and vein ligated at the site of injury. A lumbar paravertebral sympathetic injection with novocaine was done on the 16th and 17th of March. Forty thousand units of gas gangrene antitoxin was given intramuscularly. A plaster hip spica encasement was applied for the immobilization of the soft-tissue wounds and the patient evacuated to a General Hospital March 23, 1944.

On March 24, the toes were fairly warm but no pulsations could be felt in the foot; the color was good, however, and there was no swelling. There were two large wounds, anterior medial and the lateral surface of the thigh with some induration of the exposed muscle. On March 24, 1944, a transfusion of 500 cc. of blood was given and the following day the plasma protein was 8.3 Gm.; hemoglobin 15 Gm., and hematocrit 44 per cent.

On March 27, 11 days after the débridement, the wounds were closed with end-on-mattress silk sutures after trimming the skin edges.

Progress Notes—April 5: "Sutures removed, the wounds are healing cleanly."

April 11: "Posterior tibial pulse cannot be felt. The dorsalis pedis is present but weak. The toes are normal color, there is no swelling, the left foot is slightly cooler than the right."

April 24: "There is a small area on the left heel which has purplish discoloration and a vesicle has formed, probably the result of pressure from the splint. He has been walking fairly well."

SYMPATHECTOMY FOR ISCHEMIA

May 11: "The area on the left heel has almost covered over with epithelium now. The posterior tibial and dorsalis pedis pulses are present but weak. The left foot is cooler than the right on cool days and the color of the foot is normal."

June 1: "It is now three months since the injury and ligation of the vessels. The vessels of the involved foot can be felt but pulsate weakly. On cool days the pulsation cannot be felt and there is a difference in the temperature of the two feet. The color is normal and there is no swelling. He does not have excessive sweating of the feet. The calf cramps after walking 800 to 1,200 yards at a moderate rate of speed."

Disposition: Sent to limited duty in the Mediterranean Theater.

Case 2.—A 23-year-old Infantry Private was accidentally shot by another soldier, at 2030 hours, May 15, 1944, at Anzio Beachhead in Italy. He was given 1 cc. of tetanus toxoid and 250 cc. of plasma at the Battalion Aid Station, then was taken to a Field Hospital. At 0100 hours, May 16, 1944, 4.5 hours after injury, the wound was débrided and the left femoral artery and vein ligated in the mid thigh, distal to the profunda femoris branch. Lumbar sympathetic novocaine injections were done daily for three days. Sulfadiazine, 1 Gm. every four hours was given orally following the operative procedure. On May 23, the wounds were sutured under local novocaine anesthesia. He was evacuated to a General Hospital, May 26, where examination showed the wounds to be healing cleanly. The left foot was cooler than the right and both feet were sweaty. The pulsations could not be felt in the left foot vessels. There was no swelling of the foot and the color was good. The plasma protein was 6.6 Gm., hemoglobin 11.8 Gm.; hematocrit 34.5 per cent.

Progress Notes.—May 29: "Transfusion 1,000 cc. of whole blood."

June 20: "Cold day, both feet cold and moist, pulses in the left foot are not palpable, color slightly cyanotic."

July 8: "The posterior tibial pulse can now be felt. The dorsalis pedis is very weak. The feet are about the same temperature, both sweaty and cold. He can walk about 400 yards slowly without pain but gets cramp in the calf on climbing two flights of stairs at moderate speed."

July 31: "(Cool day) The left foot is cooler than the right, both are sweaty and he can walk only 200 to 300 yards at moderate speed before getting pain in the left calf (two and one-half months after injury)."

August 10: "Left lumbar sympathectomy performed under spinal anesthesia, through an anterior muscle-splitting extraperitoneal approach. The second and third lumbar ganglia and connecting sympathetic trunk were excised."

August 26: "The abdominal wound healed cleanly. He can walk ten times the distance he could prior to sympathectomy at the same rate of speed without cramping in the calf (16 days after operation)."

September 20: "He walked one and one-fourth miles today at a brisk pace without pain (one month and ten days postoperative)."

"The foot and leg are warm and dry, there is no swelling, and the left foot is warmer now than the right. The posterior tibial pulse is fairly strong."

Disposition.—Limited duty in the Mediterranean Theater four months after injury and one month and ten days after sympathectomy.

Case 3.—A 26-year-old Infantry Private sustained multiple penetrating wounds by enemy shell fragments, at 0800 hours, June 1, 1944, near Rome, Italy. He received 250 cc. of plasma and 1 cc. of tetanus toxoid at the Battalion Aid Station, and was then sent to a Field Hospital where, at 1320 hours, June 1 (five and one-half hours after injury) the wounds were débrided. There was extensive muscle destruction of both anterior thighs, especially the left, and the left femoral artery and vein had been severed distal to the profunda femoris branch. The vessels were ligated and plaster splints applied to both lower extremities for soft-tissue immobilization. He was evacuated to a General Hospital, June 6, 1944, where examination showed extensive wounds of both anterior thighs with some necrotic tissue in the wounds. The pulses of the left foot

could not be felt, the color was pale, there was no swelling and the left foot was slightly cooler than the right.

Progress Notes.—June 7: "Plasma protein 6.6 Gm.; hemoglobin 9.2 Gm.; hematocrit 27 per cent.

June 8: "Transfusion 1,000 cc. of whole blood."

June 9: "Transfusion 1,000 cc. of whole blood. Wounds closed after excising the necrotic tissue from the thigh wounds and mobilizing skin flaps by undercutting. Drain left in right thigh wound. Penicillin 25,000 cc. every three hours, given from June 8 until June 13."

June 11: "Plasma protein 7.3 Gm.; hemoglobin 13.7 Gm.; hematocrit 40.5 per cent."

June 20: "Sutures removed, moderate purulent reaction about sutures and small deep pocket of pus at upper angle of left thigh wound. Hot dressings applied."

June 27: "Wounds healing satisfactorily."

July 12: "Patient walking about and getting physiotherapy. He has marked weakness of muscles of both thighs but the left is more marked than the right."

August 1: "(Two months after ligation of artery.) The left foot is cooler than the right and the left foot pulses are weak. He has cramping pain in the left calf after walking up two flights of stairs at a moderate speed."

August 10: "(Two and one-half months after injury.) Left lumbar sympathectomy performed through an anterior muscle-splitting abdominal incision using the extra-peritoneal approach. The second and third lumbar ganglia and connecting trunk were excised. (Spinal anesthesia.) Some enlarged lymph nodes were encountered in reflecting the peritoneum over the sympathetic chain."

August 13: "Temperature elevated to 102–103° F. Pain and tenderness deep in left flank. The wound was explored under pentothal anesthesia. Moderately large collection of thin, bloody purulent exudate in retroperitoneal space evacuated. Two drains (cigarette) inserted. Culture of fluid showed *beta hemolytic Streptococci*. Penicillin 25,000 units every three hours and sulfadiazine 3 Gm. followed by 1 Gm. every four hours started."

August 17: "Temperature and pulse have gradually declined. The left foot has been dry and warmer than the right since the sympathectomy, color of foot is normal. Posterior tibial pulse fairly good volume, no swelling."

September 3: "Temperature elevated again, and some pain in the left flank. Digital exploration, under pentothal anesthesia, revealed small pocket beneath fascia with inadequate drainage."

September 16: "Patient afebrile, wound healing, drain removed."

October 7: "Sympathectomy wound almost healed now, the patient is taking daily walks with gradual improvement. He has considerable general weakness from sepsis and long hospitalization, plus local weakness of the thigh muscles from muscle destruction by the fragments."

October 11: "The posterior tibial and dorsalis pedis pulses are palpable and strong on left. The left foot is dry and warmer than the right. There is no swelling and the color is normal. He can walk 1,200 yards at a moderate speed. General weakness and local weakness in thigh prevent further walking now. No pain experienced in the left foot after walking this distance, also no pain after walking up stairs."

Disposition.—Evacuation to Zone of Interior (four and one-half months after injury, two months after sympathectomy).

Case 4.—A 28-year-old Infantry Sergeant was wounded in action by enemy bullet, at 2400 hours, August 19, 1944, in Southern France, sustaining penetrating wounds in the hip, left thigh, and right heel with laceration of the right femoral artery and vein. He received 1 cc. of tetanus toxoid and 750 cc. of plasma at the Battalion Aid Station at 0120 hours. The patient was then sent to a Field Hospital where the wounds were débrided and the femoral vessels divided and ligated at the site of injury below the

SYMPATHECTOMY FOR ISCHEMIA

profunda femoris branch. The exact time was not stated, but was probably within a few hours after the injury, on August 20, 1944.

Lumbar sympathetic injections of novocaine were done daily for three days. Penicillin 15,000 cc. every three hours was given intramuscularly. He was evacuated to a General Hospital in Italy, on August 25, at which time he was quite pale; plasma protein was 6.7 Gm.; hemoglobin 8.2 Gm., and hematocrit 24.1 per cent. The pulses could not be felt in the right foot, the foot was pale and slightly cyanotic and cooler than the left foot. There was no swelling.

Progress Notes.—August 25: "Transfusion 1,000 cc. of whole blood."

August 26: "Transfusion started, after receiving about 100 cc. he had a severe reaction, with back pain, numbness, and tingling of extremities, dyspnea, cyanosis, but symptoms were relieved by adrenalin. Cross-match rechecked and found compatible. Reason for the reaction not determined."

August 27: "Wounds closed (seventh day after débridement). Transfusion 1,000 cc. of whole blood during operation."

September 3: "Sutures removed, wounds healing cleanly."

October 2: "(Two months after injury) patient has cramping pain in right calf after walking 500 to 600 yards at moderate speed. The pulses remain weak, and the foot becomes quite cold and pale on cold days."

October 28: "Right lumbar sympathectomy. Spinal anesthesia, extraperitoneal, muscle-splitting, anterior abdominal incision. The second and third ganglia and connecting trunk were excised."

November 6: "The right foot has been dry and warmer than the left since sympathectomy. Pulses in foot fairly good volume. Suture removed. Wound healing clearly."

November 13: "Taking daily walks. No cramping in calf."

November 25: "(Three months after injury, one month after sympathectomy.) Patient can now walk two miles at a moderate speed without pain in the calf. The right foot remains dry and warmer than the left. There is no swelling. The color is good and the pulses of good volume."

Disposition.—Limited duty in Mediterranean Theater.

Case 5.—A Sergeant in a Tank Battalion was wounded by accidental explosion of a rifle grenade on a practice range in Northern Italy, at 1530 hours, February 14, 1945, sustaining a penetrating wound of the left anterior thigh. There was considerable bleeding from the wound, necessitating the application of a tourniquet. Treatment during evacuation consisted of the application of a dressing and the injection of one-quarter grain of morphine. He was given 1 cc. of tetanus toxoid and penicillin started. The left foot was cold and pulseless.

Operation.—February 14, 1945, 2000 hours: Under gas-oxygen-ether anesthesia, the wound was débrided, the femoral artery was found divided about three centimeters below the profunda femoris branch. The vessel was ligated and the concomitant vein divided and ligated at the same level. The metallic fragment was removed. The wound was left open. A dry fine-mesh gauze dressing was applied.

At the end of the above procedure the left foot was cold, pulseless and a cyanotic-purplish color. The general condition of the patient was good. A left lumbar sympathectomy was then done through an anterior muscle-splitting extraperitoneal approach. Lumbar ganglia II and III with connecting trunk were removed. The wound was closed in layers with fine cotton. Following the sympathectomy the left foot was almost as warm as the right. The veins were full and showed good venous flow. The color was slightly cyanotic but gradually became normal within a few hours. A 1,000 cc. blood transfusion was given during the operation.

Progress Notes.—February 15: "The left foot is hot and dry, veins full good color. Feet about equal warmth. No pulse is felt in the left foot. Plasma protein 6.2 Gm.; hemoglobin 11.2 Gm.; hematocrit 38 per cent."

February 16: "Transfusion 500 cc. of blood given. Patient has moderate tenderness and some pain on motion in left medial calf muscles."

February 20: "Patient is afebrile for two days now. Wound of left anterior thigh closed with end-on-mattress silk sutures, under pentothal anesthesia."

February 24: "Penicillin discontinued. He has been afebrile since February 21."

February 28: "Abdominal and thigh wounds are healing cleanly. All sutures have been removed."

March 14: "Plasma protein 6.5 Gm.; hemoglobin 15 Gm.; hematocrit 44 per cent."

"It is now one month following injury and operation. He has been taking daily walks and thigh exercises. Today he walked two and one-half miles on a one-quarter mile measured track at a moderate gait without experiencing cramping in the leg. He does have cramp in the calf after walking one-quarter mile at a very fast pace. The foot remains dry and warm. The posterior tibial pulse can be felt on the left. The dorsalis pedis is not palpable."

Disposition.—Evacuated to a General Hospital, and from there was sent to duty in the Mediterranean Theater.

DISCUSSION.—The inaccessibility of a medical library prevents review of the literature on this subject. White and Smithwick² make the following statement about sympathectomy upon patients with arteriosclerosis and thrombo-angiitis obliterans who have associated vasospasm: "Besides improvement in the circulation to the skin and subcutaneous tissue, muscular circulation may also occasionally benefit, as judged by improvement in or disappearance of intermittent claudication."

The common stimuli which cause vasoconstriction are cold, pain, fear, anger, asphyxia, hemorrhage and dehydration. In any but the warmest climate, and under the most ideal circumstances, one is apt to experience many of these stimuli during peacetime as well as in a War Theater. In three cases the effect of cold stimulus could be seen repeatedly before sympathectomy.

The number of cases presented is too small to attempt to draw any broad conclusions from them. The results do, however, indicate that the recovery can be hastened and is probably more complete, with less disability resulting in those cases having sympathectomy performed following the division of the femoral artery.

SUMMARY

Five cases are presented, all of which had ligation of the femoral artery and vein between the profunda femoris branch and Hunter's canal. All cases were between the ages of 20 and 30 years. All cases had intermittent claudication in the calf of the involved extremity after walking a short distance at a moderate speed. The greatest distance any patient could walk at this speed was 800 to 1,200 yards prior to sympathectomy. The average distance of the four observed two months or more following ligation of the vessels was 500 to 600 yards. One case having sympathectomy immediately after ligation of the vessels walked two and one-half miles, over a measured course at a moderate rate of speed, one month following the operative procedures.

SYMPATHECTOMY FOR ISCHEMIA

TABLE I
SUMMARY OF DATA ON 5 PATIENTS UPON WHOM SYMPATHECTOMY WAS PERFORMED FOR ISCHEMIA

Case No.	Date of Injury	Age	Time-Interval between Injury and Ligation of Vessels	Immediate Postoperative Novocaine Lumbar Sympathetic Injection	General Supportive Measures—Oxygen, Blood, Position, etc.	Hematocrit	Distance Walked at Moderate Speed before Cramping in Calf Occurred	Time-Interval between Ligation of Vessels and Sympathectomy	Distance Walked Following Sympathectomy at Moderate Speed	Disposition
1.	16 March, 1944	24	3 hours	Yes, for 2 days	None immediately. Postoperative transfusion 500 cc. blood, 24 March, 1944	44.5%, 24 March, 1944	800-1,200 yards, 3 months after injury	Sympathectomy not done	Walked 1.25 miles without cramping, 1 month and 10 days after sympathectomy	Limited duty 3 months after injury
2.	15 May, 1944	23	4.5 hours	Yes, daily for 3 days	None immediately. Postoperative 1,000 cc. blood transfusion, 29 May, 1944	34.5%, 28 May, 1944	200-300 yards, 2.5 months after injury	2.5 months	Walked 1.25 miles without cramping, 1 month and 10 days after sympathectomy	Limited duty 4 months after injury
3.	1 June, 1944	26	5.5 hours	None recorded	Plasma 500 cc. prior to operation. 2,000 cc. blood transfusion, 8 June, 1944	27%, 7 June, 40%, 11 June	After walking up 2 flights of stairs, 2 months after injury	2.5 months	1,200 yards without cramping. Muscle loss in thigh prevented further walking (See case report)	Evacuated to Z.I.
4.	19 August, 1944	28	Time not stated. (Less than 24 hours)	Yes, daily for 3 days	750 cc. of plasma at Bn. Aid Sta. Transfusion 1,000 cc. blood, 25 August, 1944. Transfusion 1,000 cc. blood 27 August	24.1%, 25 August, 1944	500-600 yards, 2 months after injury	2 months	2 miles at moderate speed without pain, 1 month following sympathectomy	Limited duty 3 months after injury
5.	14 February, 1945	28	4.5 hours	Sympathectomy immediately following ligation of artery	1000 cc. blood transfusion during operation. 500 cc. blood transfusion, 16 February, 1945	38%, 15 February, 1945	Patient walked 2.5 miles at moderate speed, 1 month after injury, with no cramping in the extremity			Limited duty 6 weeks after injury

All cases having sympathectomy showed a decided improvement in the blood supply of the involved extremity.

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BRIEF COMMUNICATIONS

FIBROSARCOMA PROTUBERANS

ARISING ON AN OLD BURN SCAR

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THE FOLLOWING CASE is reported because fibrosarcoma protuberans is not a common condition arising on an old burn scar. This condition is called dermatofibrosarcoma, of Darier, or dermatofibrosarcoma protuberans, by Hoffman. It is interesting to note that the original lesion was a dermatofibroma which eventuated into fibrosarcoma.

Case Report.—W. H., a painter, age 48, married, white, was referred by me to University Hospital, November 16, 1944, complaining of generalized weakness, loss of weight, and a mass on the left chest wall.

Present History: About two years previous, patient noticed a smooth marble-sized mass in the left lower chest about three inches below the nipple. At first this was tender on palpation, and was covered with normal skin. This was treated by his local physician with ointments. The tumor gradually grew and finally ulcerated. During the last four months the mass has grown rather rapidly, and has become purulent.

Past History: Negative except in the last year patient has developed a rather persistent cough with loss of weight. When the patient was six years of age, his clothes became ignited and he was severely burned over the lower part of the face, neck, left chest and left arm. He was hospitalized for six months, and thereafter was confined in and out of bed for six years because the area did not heal. At age 13 he was operated upon for adhesions between his left chest wall and arm. This apparently was not successful. For the past seven months, the patient has been unable to work as a painter because of generalized weakness and injury to the mass while working.

Physical Examination: The patient was a thin, small man, appearing much older than his age, with marked scarring of the face, chest, and left arm. There is a large band of adhesions between his left chest wall and arm extending from the axilla midway down his arm. Over the left lower chest wall there is a large, cauliflower, fungating, purulent, ulcerative mass, about four inches in diameter, protruding about three inches (Fig. 1). The mass is rather hard and bleeds very readily upon the slightest disturbance. There are no subjective symptoms. The mass has a foul odor, and is firmly adherent. His temperature ranged between 100°–102° F.

Roentgenologic Examination: No evidence of any pulmonary or rib disease.

Biopsy Report: The nodule is composed of a mass of neoplastic tissue which consists of spindle-shaped cells with a large, very pleomorphic nuclei which are pale-staining and vesicular, with prominent nuclei. Many giant and bizarrely lobulated nuclei are seen as well as multinucleated giant cells. Mitoses are infrequently seen. **Histologic Diagnosis:** Fibrosarcoma (Fig. 2).

Laboratory Studies.—Sternal Puncture: The marrow preparations are very cellular and show the following distributions:

Cellular Distribution	Percentage
Myeloblasts	0.6
Premyelocytes	1.0
Myelocytes	20.2
Metamyelocytes	57.6
Mature neutrophils	12.0
Eosinophils	1.6
Basophils	0.4
Lymphocytes	3.0
Erythroblasts	0.4
Normoblasts	3.2
M. E. ratio equals 26:1 (myelogenic-erythrogenic)	



FIG. 1.—Showing the large protruding vascular tumor arising from scarred tissue of the left chest wall. Note the adhesions between inner arm and chest wall.

FIBROSARCOMA PROTUBERANS

This represents a very marked myeloid hyperplasia. Numerous counts revealed a picture similar to one below:

Blood Count

Hb. 11 Gm. per 100 cc. equals	71.5%
Erythrocytes	3,730,000
Leukocytes	49,500
Polys	93%
Lymphs	4%
Monocytes	2%
Myelocytes	1%
Color index	.93

Actual Count

46,035	Filament	45
1,980	Nonfilament	48
990		
495		

The blood and bone marrow picture are consistent with a leukemoid reaction, such as one may see in malignancy.

Serum protein, 6.4. Blood serology, negative. Urinalysis, negative.

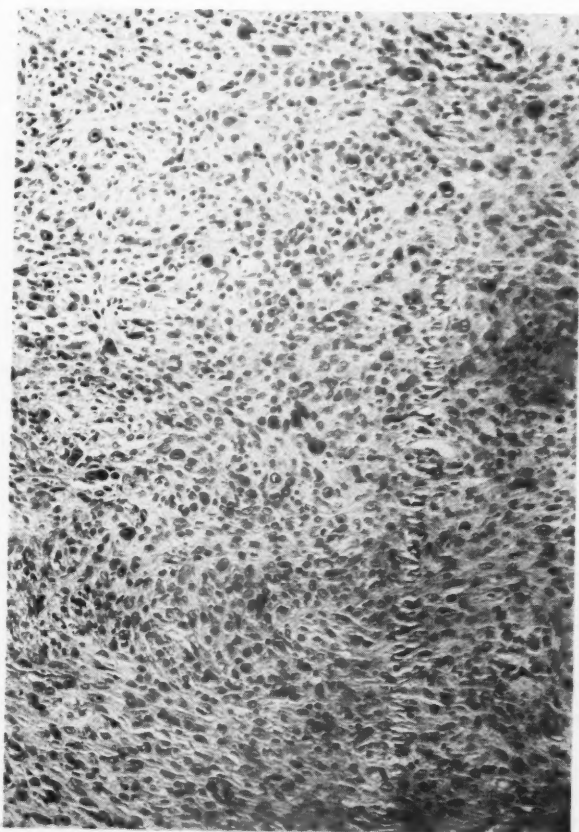


FIG. 2.—Section showing spindle-shaped cells with very large pleomorphic nuclei. Many giant and bizarrely lobulated nuclei are seen as well as multinucleated giant cells.

Surgical Opinion: The surgeon was of the opinion that he had nothing to offer this patient in the form of radiation therapy, either by roentgen ray, radium or radon. The diagnosis of fibrosarcoma contraindicated radiation

therapy, as the spindle type of cell is usually very resistant to irradiation. This, coupled with the fact that the patient had an extensive burn scar, and that this tumor had arisen in this type of tissue, contraindicates roentgenotherapy. The extensive ulceration and infection involving the tumor has left no normal tissue, and any treatment given to this area would only help to further necrosis and sloughing. Surgery, likewise, has little to offer, inasmuch as it would necessitate wide surgical resection, possibly even removal of some ribs followed by extensive plastic procedures, from which the patient may never recover.

Senear, Andrew and Willis¹ reported two cases with no metastasis and Geschickter² stated that these tumors are not radiosensitive.

COMMENT AND CONCLUSIONS

Although dermatofibrosarcoma is not a common condition, it is unusual in that it developed on an old burn scar. In most of the cases reported,³ no metastasis has occurred, and the condition was cured after complete surgical removal. The microscopic picture is that of a spindle cell sarcoma intermingled among fibrous connective tissue. This condition is usually asymptomatic, and the general health is very little affected.

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INTESTINAL OBSTRUCTION DUE TO PERSISTENCE OF THE OMPHALOMESENTERIC ARTERY

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THE PERSISTENCE of the omphalomesenteric vessels in man is a rare congenital anomaly similar in nature to the persistence of a Meckel's diverticulum. Indeed, the two may be associated. There is no doubt that Meckel's diverticula are seen much more frequently than are vascular remains, as shown by the multitudinous reports of cases in the literature on the former. In spite of their rarity in man, Allen¹ has shown that such vessels are very frequently found in new-born cats, dogs and guinea-pigs. The embryology and usual fate of these fetal structures should be reviewed before their nature can be analyzed.

EMBRYOLOGY^{2, 3, 4, 5}

Meckel's Diverticulum.—The yolk sac, an extracoelomic structure formed to nourish the developing embryo, is connected to the digestive tract of the fetus by an elongated, narrow stalk which is variously termed the yolk stalk, vitelline duct or omphalomesenteric duct. The latter is incorporated in the umbilical cord and is accompanied by the omphalomesenteric artery and vein which lead to and from the yolk sac. The yolk sac normally loses its connection with the intestine in the embryo of 7 mm. (six weeks), and the omphalomesenteric duct soon degenerates. The time that this occurs is variable and the sac may be present even in an embryo of 12.5 mm. As a rule, the vessels persist for a slightly longer period after the duct has disappeared.

Anomalous persistence of the duct is referred to as a Meckel's diverticulum. A diverticulum of this type usually takes one of several forms. It may establish a fistulous tract from the terminal ileum to the umbilicus or it may persist as a blind sacculum from the intestine. The out-pouching is usually free at its distal end, but it may be anchored by a fibrous cord or by vessels to the umbilicus.

Omphalomesenteric Artery.—The aorta in the embryo sends, primitively, the paired omphalomesenteric arteries to the yolk sac. These pass through the mesentery of the intestine, one on each side of the intestine, to the yolk sac. The paired arteries fuse in those portions that course through the mesentery and coelomic cavity. The mesenteric segment of the vessel is destined to become the future superior mesenteric artery. Usually, the left limb of that part encircling the bowel disappears and a single omphalomesenteric artery which passes entirely on the right side of the intestine remains (Fig. 1). Normally at about the sixth week of intra-uterine life that portion of artery between intestine and umbilicus disappears.

Persistence of the omphalomesenteric artery in man is seen only occasionally. When present it may coexist with a Meckel's diverticulum or may be found either alone as a free cord (being attached only at one end) or uniting the mesentery of the terminal ileum to the anterior abdominal wall, usually in the vicinity of the navel. Whether the right or left limb of the early arterial ring has persisted, will determine on which side of the intestine the vessel will course. If the left limb remains, the artery will course to the left side of the intestine.

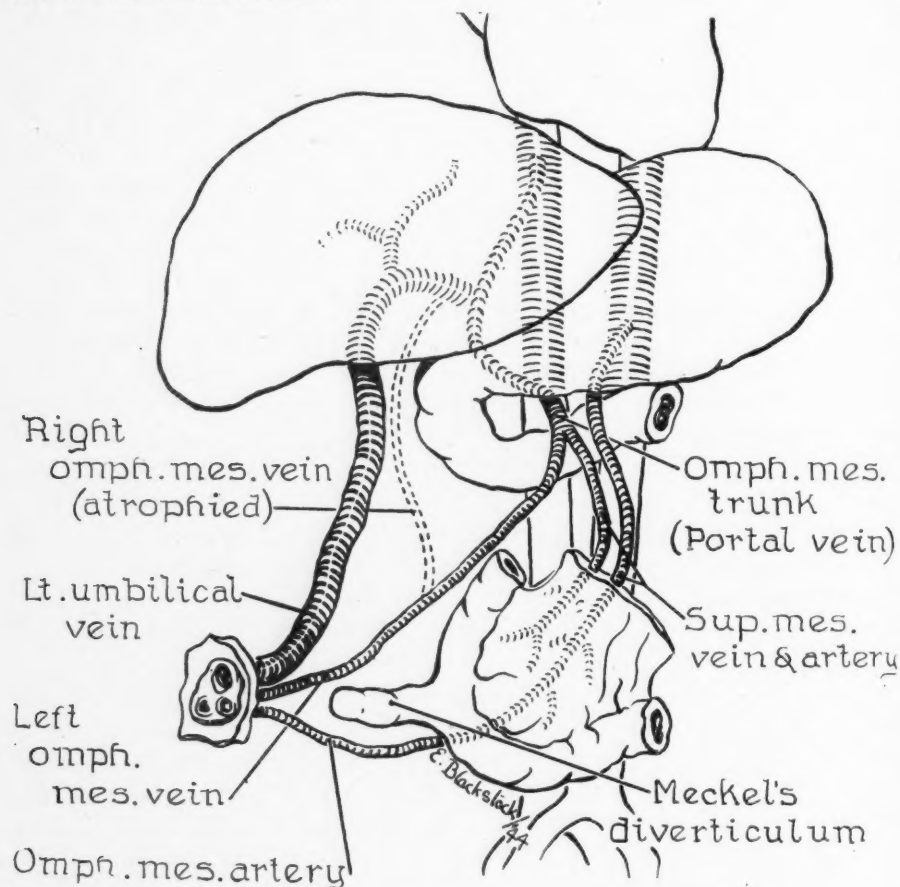


FIG. 1.—Embryologic structures in the region of the umbilicus.

Omphalomesenteric Vein.—The omphalomesenteric veins are paired, arise from the yolk sac, and empty into the right and left horns of the sinus venosus of the primitive heart. The veins in their course into the sinus venosus are interrupted by growth of the liver bud, and very soon the left vein is broken up to form liver sinusoids. These still drain into the left horn of the sinus venosus. At this time the left umbilical vein anastomoses with the liver sinusoids, and the right umbilical vein atrophies. Three anastomotic channels are next formed between the omphalomesenteric

veins before their entrance into the liver. These are in the region of the intestine which is destined to become duodenum and which they encircle. Certain of these anastomotic channels along with the right omphalomesenteric vein atrophy and disappear and a common S-shaped omphalomesenteric trunk reaches the liver. The trunk receives the superior mesenteric vein at the level of the middle anastomotic channel, and from this point to the liver the trunk later forms the portal vein (Fig. 1). Normally the portion of the vein from the umbilicus to the duodenum (in the region of the head of the pancreas) vanishes at about the sixth week of embryonic life. When this vessel persists, it is usually present in a similar fashion as is the omphalomesenteric artery. It may be present either alone, as a band, or in conjunction with a Meckel's diverticulum.

Case Report.—The patient, a 38-year-old male, was admitted to Dr. W. E. Gallie's service, with acute small bowel obstruction. Four days before admission there was a sudden onset of crampy abdominal pain which was followed within an hour by vomiting. The pain became progressively more severe. Emesis continued with increasing frequency, and later the vomitus became fecal. There were no bowel movements during this period.

A similar attack of abdominal pain had occurred two weeks prior to admission and at various intervals during the last two years.

Physical examination revealed marked abdominal distention. No localized abdominal tenderness was elicited and no masses were palpable. A slight amount of free fluid was present in both flanks. Surgery was contemplated after a course of preoperative preparation (Miller-Abbott tube and intravenous fluids), but the patient began to have respiratory distress due to atelectasis of the right lung. He died 12 hours after admission.

Necropsy.—A firm, round, tapering cord covered by peritoneum, extended from the umbilicus to the mesentery of the small bowel. The cord was 6 cm. in length, passed to the right of the bowel, and was inserted in the mesentery 3 cm. away from the attached border of the ileum and 20 cm. proximal to the ileocecal junction. No gross vascular communications at either end of the cord were found. The umbilical end of the cord was of greater thickness, measuring 8 mm. in diameter, whereas, the mesenteric end measured 4 mm. The small bowel had looped itself about the cord and was enormously distended and discolored but still viable. Two hundred cubic centimeters of fluid were found in the flanks and pelvis. No other developmental abdominal defect was present.

The bronchi contained mucous plugs, and atelectasis of both lungs (more marked on the right) was found. The remaining viscera showed no abnormalities.

Histologic Examination: Cross-sections of the band through the umbilical and mesenteric ends and through the midportion were examined. The center in all sections was occupied by a thick-walled muscular artery having an internal and an external elastic lamina (Fig. 2). Red blood cells were present in the lumen. The artery was immediately surrounded by a fibromuscular zone of connective tissue which was rich in coarse elastic fibrils and which contained several nerve fibers. The remainder of the band was made up of fat and loose areolar connective tissue. This was most pronounced through the umbilical portion and accounted for the greater thickness of the cord in that area. The outer surface of the cord was covered by peritoneum.

No vestigial intestinal or venous remnants were found in the sections.

DISCUSSION.—Meckel⁶ contributed much to the present subject. He

established the fact that the vascular remnants are due to embryologic maldevelopment rather than to a postinflammatory reaction. Fitz,⁷ in a comprehensive paper on "persistent omphalomesenteric remains" in which he reviewed the embryology of the umbilical region, furnished strong confirmation of Meckel's views.

Of the vascular remnants the artery persists more frequently, since only two cases of a persistent omphalomesenteric vein have been encountered in the literature. One of the cases in which the vein was patent and connected the navel with the superior mesenteric vein was reported by Spangenberg.⁸

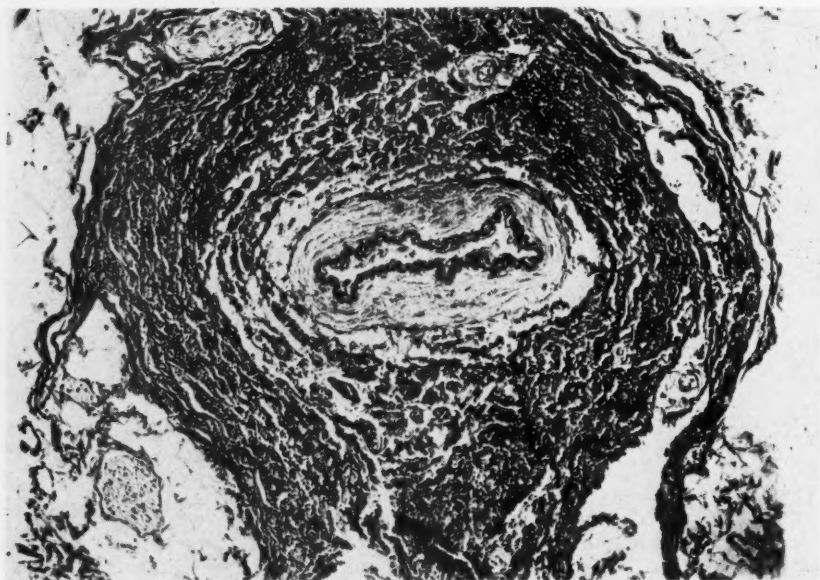


FIG. 2.—Cross-section of the umbilical band. (Weigert's elastic tissue stain, $\times 75$)

The other was presented by Buchanan and Wapshaw.⁹ The course of the band in the latter case coincided with that taken by the omphalomesenteric vein, *i.e.*, originating at the umbilicus, proceeding upward on the surface of the mesentery of the small bowel, and ending retroperitoneally in the region of the third part of the duodenum. Histologically, the band contained three thick-walled veins in addition to fat and areolar connective tissue.

The relationship of a persistent omphalomesenteric artery to the abdominal viscera varies widely but usually falls into one of three groups as listed below:

1. The most common persistence is in the form of a band or cord extending from the anterior abdominal wall in the region of the umbilicus to the mesentery of the small bowel a short distance proximal to the ileocecal valve. This was true in our case, and was also shown in the case reported by Mahomed,¹⁰ in which the vessel took origin from the anterior abdominal wall midway between the umbilicus and pubis, was inserted into the mesentery of the ileum about three feet from the ileocecal valve, and terminated in a large branch of the ileocolic artery.

2. It may be found as a band in association with a Meckel's diverticulum.

A good example of this can be seen in a case reported by King,¹¹ in 1843, in which a Meckel's diverticulum was adherent to the umbilicus, forming a fecal fistula, and in which an "adventitious cord" was found passing from the mesentery to the midpoint of the diverticulum. The band had compressed the ileum just distal to the intestinal attachment of the diverticulum. This cord was presumed to be a persistent artery. Another variant of this anomalous coexistence is offered in the case report of Derbes and Hoge.¹² In their case, the omphalomesenteric artery accompanied the diverticulum which was attached to the navel by a fibromuscular structure. The latter was thought to be the obliterated portion of the diverticulum. The arterial remnant communicated at the navel with the inferior epigastric and with the obliterated hypogastric arteries and at the mesenteric end with an ileal branch of the superior mesenteric artery.

3. The least common form of persistence is that of a cord attached only at one end. The attachment may be either at the umbilicus or on the mesentery. The free end is usually rounded and is seen floating in the abdominal cavity. Ruge¹³ and Gautier¹⁴ have observed such findings.

Persistence of the omphalomesenteric artery is a constant menace because of the complications that it may produce. At times, however, it is found incidentally, apparently causing no symptoms. Tuberculosis was the cause of death in the case of a dissecting room cadaver, reported by Derbes and Hoge.¹² The hospital record contained no history referable to the abdomen or gastro-intestinal tract. An apparently symptomless persistent omphalomesenteric artery was found by Gisel¹⁵ in a new-born child dying of an intracranial hemorrhage.

Mild symptoms are sometimes produced, as illustrated in a report by Shaw¹⁶ who had performed an hysterectomy for vaginal bleeding and incidentally found a band, which proved to be an anomalous artery, stretching from the mesentery of the ileum to the anterior abdominal wall in the region of the right inguinal ring. This had transfixed the omentum in the right lower quadrant and apparently had caused a chronic aching pain in the right iliac region.

The commonest complication of a persistent omphalomesenteric artery is intestinal obstruction. This may be due either to looping of the bowel about the cord, as was the event in the present case, or to herniation of the bowel through a loop, as in one of the cases cited by Fitz,⁷ from the Warren Museum. The obstruction may be due to kinking alone, as was illustrated by King.¹¹

Intra-abdominal hemorrhage from a persistent vessel is indeed a rare complication. Fraser and McCartney¹⁷ reported a case in which this finding was present 48 hours following cauterization of the umbilicus for "granulation tissue." The vessel had ruptured at the mesenteric attachment causing the formation of an hematoma which, in turn, had ruptured into the peritoneal cavity.

The case under consideration is of interest for several reasons. On account of the history of several attacks of abdominal pain, one must assume

that looping of the intestine about the vessel had occurred at various intervals. Unwinding of the involved loops of bowel was spontaneous until the last attack. In view of several such abdominal catastrophes, with impending to full-blown intestinal obstruction, in the absence of visible herniae, a persistent omphalomesenteric vessel must be considered in addition to the other causal factors.

At autopsy, even though no gross communication of the persistent artery with other vessels could be found, there is no doubt that such a connection had existed, since red blood cells were present microscopically in the lumen of the vessel. It is evident that during embryonic development it was the right limb of the artery that persisted, since the vascular remnant imbedded itself in the mesentery of the ileum to the right of the intestine.

SUMMARY

A case of intestinal obstruction due to a persistent omphalomesenteric artery is presented, together with a review of the embryology of the umbilical region. Obstruction is the most frequent complication of this anomaly, intra-abdominal hemorrhage being much more rare.

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